NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

REENGINEERING HUMAN PERFORMANCE AND FATIGUE RESEARCH THROUGH USE OF PHYSIOLOGICAL MONITORING DEVICES, WEB-BASED AND MOBILE DEVICE DATA COLLECTION METHODS, AND INTEGRATED DATA STORAGE TECHNIQUES

by

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ABSTRACT

In the field of human research, particularly in operational environments, data collection techniques are difficult. Researchers often focus their efforts on the data analysis and overlook the shortcomings of their data collection and storage methodologies. In order to demonstrate effective data collection and storage methodology in a representative human research process, the process used by human fatigue and performance researchers at the Human Systems Integration Lab at Naval Postgraduate School (NPS) served as a Proof of Concept. Most recent studies conducted at NPS provided a model of the current process. The Knowledge Value Added (KVA) methodology was used as a tool of comparison of the current process to the reengineered process. Information technologies including wireless physiological monitoring devices, web-based and mobile device data collection methods, and integrated data storage techniques were incorporated in the reengineering effort. The data storage process included the design of a standard relational database format allowing research teams to easily access their data. This repository also enables data to be archived for future use (e.g., meta-analyses). To demonstrate the reengineered process in an operational environment, a field fatigue study was conducted at the Naval Officer Indoctrination School (OIS) in Newport, Rhode Island.

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I. INTRODUCTION

A. OVERVIEW

Data collection in the field of human research is intrinsically difficult. Monitoring physical and psychological behaviors through various data collection media and integrating the collected data points comprehensively for effective and timely analysis is a challenge in a carefully controlled laboratory environment. However, when the collection takes place in operational environments, the complexity intensifies. Often, the research team becomes focused on data analysis and they overlook major shortcomings in their collection and storage methodologies. Collecting human performance and fatigue data are one of the most complex research areas in the field of human research. In order to demonstrate effective data collection and storage methodology in a representative human research process, the process used by fatigue researchers at the Human Systems Integration Lab at Naval Postgraduate School (NPS), Monterey, California, served as a Proof of Concept. Various information technologies were considered in efforts to streamline the data collection and storage processes to improve the productivity of human research conducted under operational conditions.

This process used in recent studies conducted by faculty and students at NPS of collecting and analyzing human performance and fatigue data were evaluated and reengineered. Web-based data collection methods and mobile communications devices were incorporated in the redesigned data collection sub-process enabling additional data points to be collected in a more efficient and timely manner with greater accuracy. The data storage process was redesigned as well by establishing a standard relational database format allowing research teams to easily access their data. This repository also enables data to be archived for future use (e.g., meta-analyses). A study was conducted at the Naval Officer Indoctrination School (OIS) in Newport, Rhode Island to demonstrate the newly optimized process.

B. BACKGROUND

To improve the real life human performance, human research must be conducted in operational settings. Because of the difficult challenges environmental conditions place on such research, it is even more important for researchers to collect data efficiently and as unobtrusively as possible. There is often only one chance for data collection. Since so much is at stake under these conditions, it is essential that perhaps the only chance to capture human statistics under such circumstances not be lost due to poor data collection methodology. Of all of the areas of human research, fatigue as it relates to human performance is particularly complex. Additionally, it has become of increasing concern for the military as the force has been tasked to accomplish more with less people.

Fatigue management has become a significant issue in effective warfighting. The news media, embedded with the forces on the ground and at sea during the war in Iraq, continuously reported the sleep deprived state of the men and women serving in the armed forces and the potential dangers fatigue had on their vigilance while operating technical systems. The awareness of the consequences of fatigue continues to grow. As this occurs, a desire for innovative solutions to mitigate the given combat circumstances and achieve maximum human performance is at a record high.

At NPS, the current process of collecting fatigue data in an operational environment, analyzing the data, and publishing the results takes about a year to complete. The researchers for this process are thesis students who require significant training in the science of conducting human research as well as how to use the collection equipment and analysis tools available to them at NPS. In order to arm future sleep research teams with the ability to identify sponsoring organization's fatigue issues in a timely manner, the current fatigue study process has to change. Using this current process, identifying potential danger areas is the extent of the analysis. There is little time available to propose innovative solutions for the sponsoring organization. The new process must reduce the time required to conduct the study and provide for collection of enough quality data to enable the team to draw conclusions and recommend solutions or at the least, identify areas to focus further study if required. Additionally, a capability to enable meta-analysis of many studies conducted by NPS students and faculty would clearly provide a powerful tool not currently available as data are stored in disparate structures using many unique systems.

C. RESEARCH QUESTIONS

- How much can the productivity of the current process of data collection of human performance and fatigue data during studies conducted at the NPS be improved through redesign using information technology?
- How will web-based technology facilitate data collection in the process redesign?
- How will modern database technology enable efficiently structured data storage in the process redesign?
- How will current mobile personal computing device (PDA) technology facilitate data collection and integration in the process redesign?
  - How will performance testing using a PDA aid the process redesign?
  - How will development of a PDA based tracking log give support to process redesign?

D. SCOPE OF THESIS

In efforts to improve data collection and storage processes in the field of human research, the current fatigue study process at NPS was examined as the Proof of Concept. The process was analyzed, evaluated, and reengineered using information technology to provide an optimal solution. The most significant areas of improvement included the innovative data collection and data storage methods. The optimized model was tested as data were collected, analyzed, and stored. After necessary revisions to the model, an operational study was conducted at the Navy OIS in Newport, Rhode Island to validate the reengineered process. The scope is limited to the collection and storage of data. Research efforts toward interpretation of the data collected during this study were focused to validate the reengineered process rather than identify issues of fatigue of the study participants.

E. RESEARCH METHODOLOGY

To determine the best approach to reengineer the process, the current methods of collection and analysis were studied and the Knowledge Value Added (KVA) methodology was used. KVA provides a way to capture knowledge within a set of processes and measure its associated value. The KVA methodology provided the ability to evaluate the current process and establish a baseline for comparison to the reengineered process. The redesigned process was developed using a three tiered architecture approach and was evaluated using the KVA method. Finally, this process was tested in the Human Systems Integration Lab at NPS, fine-tuned, and was ultimately field tested at the Navy OIS in Newport, Rhode Island.

F. THESIS ORGANIZATION

Chapter II follows with a Literature Review including an overview of human performance and effects of fatigue as well as a description of the software tools used during fatigue studies for data collection and analysis. The current process of conducting these studies is outlined in Chapter III. An explanation of the process model and an evaluation using KVA analysis is provided. Chapter IV summarizes the technical approach used in reengineering the current process to include the parameters of design and the data collection and storage methods considered. Chapter V provides the model for the reengineered process and an evaluation of it using the KVA methodology. The validation of the new process is explained in Chapter VI with a description of the study conducted with the OIS participants in Newport, Rhode Island. Finally, Chapter VII concludes with recommendations for future work.

II. LITERATURE REVIEW

A. OVERVIEW

This literature review covers several diverse areas. To assist in evaluation of the data collection and storage processes of the Proof of Concept, this review is meant to provide the reader with an overall understanding of the field of sleep, fatigue and human performance and relevant research techniques. In order to adequately assess the results of the reengineered process, an introduction to the Knowledge Value Added methodology is also presented. Though the focus of this review is on the data collection techniques specific to the fatigue research process, the methods of data collection presented are intended to serve as an example of the numerous means of data collection used in human research.

The effects of fatigue and sleep deprivation on human performance have been of keen interest to those in the field of sleep research and those in the business of optimizing human performance effectiveness. This review describes human physiology and the role sleep plays in biological systems. The impact of sleep deprivation on human physiology and performance is introduced as well as reports of findings in recent dose-response studies. Additionally, current methods of data collection and analysis used to document fatigue as it relates to human performance are described.

As the military continues to require warfighters to operate under conditions of chronic sleep deprivation, the risks have become clear. Recent studies conducted by students and faculty at NPS highlight the military's continued interest in documenting the effects of fatigue on human performance in operational environments. These efforts provide the necessary evidence to implement changes enabling mitigation of risks imposed by lack of sleep. Following these descriptions, the current tools used during sleep studies by NPS research teams are introduced. This section discusses data collection tools as well as the software required to download and analyze fatigue data.

In the final section of this chapter, an overview of the Knowledge Value Added approach to assessing the value of knowledge in a given process will be introduced. This methodology provides the means to compare the current process used by these recent NPS studies to the reengineered process proposed from this research.

B. HUMAN PERFORMANCE AND FATIGUE

1. Human Physiology and the Role of Sleep

Human beings, evolving over time, have developed an internal biological clock that serves to regulate sleep and wake periods. These endogenous clocks have been described to control a number of biochemical, physiological, and behavioral phenomena in humans. Operating on a cyclic pattern, these clocks repeat approximately once per day and are called circadian rhythms. Franz Halberg of the University of Minnesota first used the word circadian as it comes from the Latin ‘circa’ (about) and ‘dies’ (day). In the late 1960s, scientists, including Jurgen Acshoff, at the Max Planck Institute in Germany isolated individuals from any external environmental cues and allowed the human participants to set their own schedules. After days of isolation, participants adjusted to a regular cycle of sleeping and waking. These scientists also discovered that the internal clock cycle repeated approximately every 25 hours (Dement, 1999).

Because the 25 hour cycle time varies slightly from the Earth’s rotation cycle, it is necessary for humans to receive environmental time cues called ‘zeitgebers’ which can help to reset the biological clock. The location of the internal clock appears to be in a small area of the hypothalamus known as the suprachiasmatic nucleus (SCN). It is sensitive to the inputs from the optic nerve. These inputs act as a controlling mechanism making necessary adjustments to the internal clock. Because of this, light is the most powerful zeitgeber for humans. Charles A. Czeisler performed several studies to demonstrate light’s influence on circadian rhythms. His results conclude that even dim light affects this circadian clock (Czeisler, 1990). Figure 1 shows the pattern for typical alertness over the course of a day. The effects of accumulated sleep dept as a result of extended wakefulness counter the effects of the biological clock. Drs. Charles Edgar and William Dement defined an opponent-process model which suggests that the alerting mechanism of the biological clock as well as a sleep drive that increases during waking hours as sleep debt accumulates are the two processes that regulates sleep in humans. The alerting mechanisms occur when a person awakens in the morning and in the late afternoon (Edgar et. al, 1993).

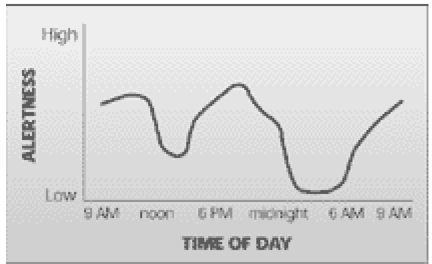

Figure 1. Alertness Over 24-Hour Period (From: Maas, 1998)

2. Performance Degradation Due to Fatigue

As neurological studies continue to examine what the brain and other body functions do during sleep, the exact activities remain largely unknown. Progress has been made in assessing the effects that sleep deprivation has on performance. Researchers agree undisputedly that total sleep restriction results in huge performance decrements. The extent of the performance degradation with partial sleep deprivation is currently the focus of much research. When comparing the effects of chronic partial sleep deprivation to the effects of complete sleep restriction, the resulting performance decrement is surprisingly similar. In a recent dose-response study conducted at Walter Reed Army Institute of Research, individuals were allowed to sleep for a restricted amount of time over a seven day period. Sixty-six people spent either 3, 5, 7, or 9 hours in bed during this period (Belenky, et. al, 2003). Over the course of the study, the participants conducted psychomotor vigilance tests to measure their simple reaction time. The participants pushed a thumb operated handheld device as a reaction to a visual stimulus. The results of their psychomotor vigilance testing (PVT) can be seen in Figure 2. As expected, PVT speeds decrease over time with the most dramatic changes seen in the group who spent three hours a night in bed. All of the participants were given a three day recovery period where there were no restrictions on sleep. After three days, none of the sleep deprived groups returned to their baseline performance speed. The conclusions drawn by the researchers suggest that the human body, in a state of chronic deprivation, adapts by stabilizing the individual's performance to a level below that of the initial baseline. This stabilization, however, prevents the rapid recovery to baseline performance. This finding is in contrast to the rapid recovery in performance seen in individuals whose sleep has been completely restricted.

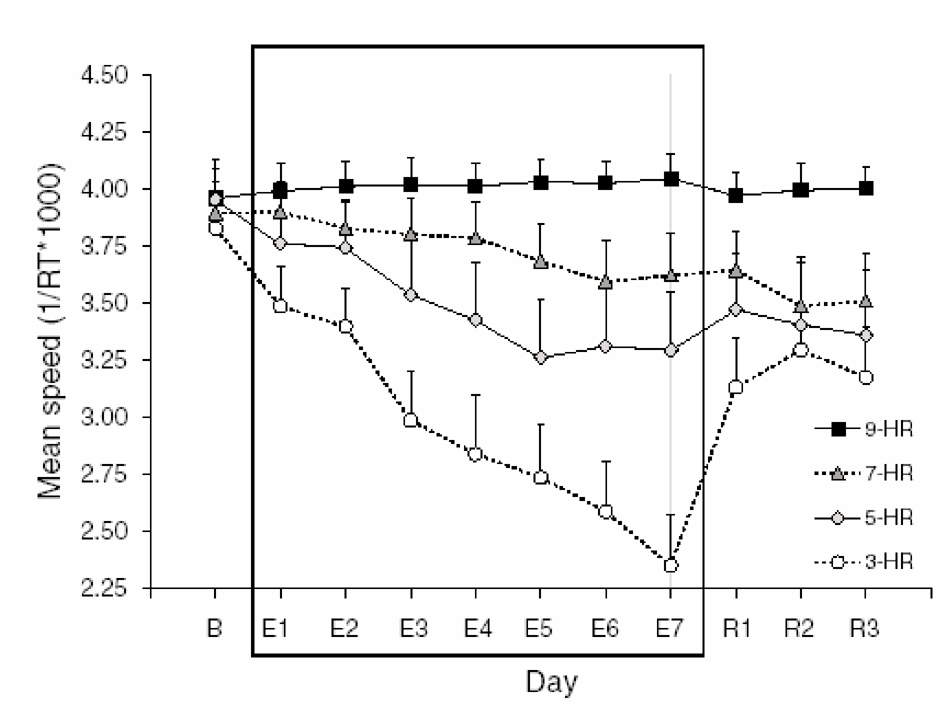

Figure 2. Mean Psychomotor Vigilance Task Speed (and Standard Error) Across Days as a Function of Time (From: Belenky, et. al, 2003)

A similar study conducted at the University of Pennsylvania restricted participants to either 4, 6, or 8 hours of sleep per night for a period of 14 days. Another group was kept awake for 88 hours. All participants were given a performance assessment battery. This battery included a psychomotor vigilance test similar to the one used in the Walter Reed study to measure behavioral alertness as well as a computerized digit symbol substitution test to measure working memory. Researchers found that subjects whose sleep period was 4 to 6 hours a night had significant deficits in cognitive performance, although the subjects reported being only slightly sleepy. Those participants who were completely deprived of sleep had cognitive deficiencies similar to the reduced sleep group; however, they reported being very tired. The results indicate that although partial sleep deprivation significantly decreases performance, individuals are unaware of this decrease in efficiency (Van Dongen, et. al, 2003). These study results present a clearer picture of possible dangers to members of the military as well as medical professionals and shift workers. In occupations where 6 hours of sleep a night or less is the norm, individuals may be operating at decreased performance levels without even knowing it. The potential risks associated with the errors made when performance degrades are alarming.

3. Data Collection Techniques (Physiology and Performance)

Human research includes the collection of both physiological and psychological data points. The field of biometrics has expanded so much recently that individuals conducting human research or simply gathering human physiological data have many wireless devices available today for data collection. From portable heart monitors to caloric intake measurement devices, innovative measurement techniques are allowing research to be conducted in much more realistic environments. The explosion of wireless technology in computing allows PDAs and other handheld devices to enable the collection of an endless assortment of data including but not limited to survey data and human performance data with minimal disruption to the individual participating in the research. As examples of some of the more intricate methods of data collection involving humans, fatigue and human performance measurement techniques provide challenges to field researchers.

Assessments of fatigue and human performance in particular have typically been accomplished within the laboratory setting using a variety of standard measurement tools. Sleep researchers frequently use electrophysiology to assess sleep. Human adults experience five stages of sleep during a typical night's sleep: stages one through four and REM (Rapid Eye Movement) sleep. Stages one through four are referred to as Non-REM (NREM) sleep. Each sleep stage has its own identifying marks as measured by electroencephalographs (EEGs), electromyograms (EMGs), and electrooculograms (EOGs). EEGs measure brain waves via electrodes pasted to the scalp. EMGs measure muscle activity and EOGs measure eye movements also using contact electrodes. The collective group of EEG, EMG and EOG measurements taken when studying sleep stages is referred to as Polysomnography (PSG). The physiologic sensor leads are placed on the participant in order to record any number of the following activities: brain electrical activity, eye and jaw muscle movement, leg muscle movement, airflow, respiratory effort, and oxygen saturation. Although these measurement techniques have proven to be very effective, they are highly sophisticated, very expensive, and extremely obtrusive to the individual.

When collecting data on participants in their work environments as the field studies conducted by NPS research teams do, less obtrusive means of measuring sleep are required. The use of actigraphy to measure movement has become the most effective means for researchers to capture sleep/wake periods of study participants in field studies. Many types of small wireless monitoring devices are available on the market today that provide the capability to measure a number of physiological activities. Wrist activity monitors or WAMs are the size of a wrist watch and contain an accelerometer that measures movement. The associated software of the WAMs use algorithms to calculate sleep and wake periods based on measured activity levels. WAMs, however, do not allow the researcher to measure brain activity. Therefore, in operational studies where WAMs are used, researchers cannot measure the stages of sleep participants reach but only can determine when the participants slept and when they were awake. Sleep efficiency can be calculated from the WAM data as a ratio of sleep epochs to actual sleep period. Sleep latency can also be calculated from the time an individual goes down for sleep until the time he is actually asleep. The various WAMs on the market today use different methods to record movement and offer different software tools to provide unique analytical techniques.

Collecting additional variables such as melatonin levels or ambient light exposure are useful techniques used in predicting circadian rhythms. Researchers measure hormone levels such as melatonin by collecting saliva or blood samples which have a distinctive circadian pattern. Other measurements such as light exposure, body temperature or subjective activity logs are useful for assisting researchers in understanding circadian patterns as well as interpreting individual behavior and predicting effectiveness.

Various techniques have been developed to measure performance or model predicted effectiveness. Cognitive testing is one approach to measuring effectiveness. Psychomotor vigilance tests including reaction time tests, running memory tests, math processing tests, and others are used by researchers to measure performance. One of the tools created specifically for field environments is the ARES (ANAM™ Readiness Evaluation System). Included in this tool is the Stanford Subjective Sleepiness Scale that identifies the particular sleepiness state felt by the participants a given time. One tool used for predicting cognitive effectiveness is the Fatigue Avoidance Scheduling Tool (FAST) built on principles of the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) Model. Analysis of data collected on participants engaged in the performance of cognitive tasks during several sleep deprivation studies conducted by the Army, Air Force and Canadian researchers is the basis for the expected level of performance effectiveness predicted by the FAST. Though designed as a scheduling tool, the FAST can serve as a model to determine effectiveness levels based on collected WAM accelerometer data.

C. RECENT STUDIES CONDUCTED AT THE NAVAL POSTGRADUATE SCHOOL

As recent studies continue to show the strong correlation between sleep deprivation and the degradation of human performance, the United States military has developed a keen interest in studying effects of fatigue on service members. Students and faculty at NPS have recently conducted studies to assess these effects in various operational environments in the Navy.

LT John Nguyen collected data on the aircraft carrier the USS JOHN C. STENNIS during a shift from day operations to night operations in support of OPERATION ENDURING FREEDOM. He used Actigraphs to collect actigraphy and sleep data and required the participants to keep a daily journal of their sleep activity. He also collected oral temperatures of the participants every three waking hours and required each participant to fill out several surveys to support his research. His thesis revealed the difficulty experienced by sailors when reversing sleep schedules from day to night operations. Additionally, LT Nguyen's data exposed significant differences between those sailors working topside and those working below decks. As a result of his findings, interest has been generated to more closely understand the effects that ambient light and other zeitgebers have on sailors in operational situations. While it is understood that mission demands may not allow optimal sleep schedules and sterile environments to be created and applied on deployed carriers, this study concluded that investigations into optimizing schedules and environments within the constraints of a given deployment may be worth the effort. Potentially maximizing human performance effectiveness as it relates to sleep deprivation in the arduous environments they face at war is the possibility highlighted in LT Nguyen's research.

During another study conducted at the Great Lakes Naval Recruiting Station, LT Brian Baldus examined the effects of changing bedtime for Navy recruits from 2100 to 2200. Using the WAMs and various subjective tests, he concluded that the change in time was significant between the two sleep conditions (Baldus, 2002). He concluded that recruits who were able to go to bed later were able to get to sleep faster and therefore sleep longer. This increase ultimately improved their performance effectiveness. Because the average ages of the study population are adolescents and young adults, the later bedtime aligned more appropriately with the known differences in adolescent/young adult circadian rhythms. Other training institutions throughout the military have shown interest in these results, prompting the desire for additional studies to find optimal sleep plans for unique circumstances in training as well as in operational environments.

Two other recent NPS theses examine sleep in operational settings (Blassingame, 2001 and Gamboa, 2002). In an analysis of archival submarine survey data collected by the Naval Submarine Medical Research Laboratory (NSMRL), LT Donnie Gamboa and LT Simonia Blassingame revealed that sailors have shown characteristics of sleep deprivation that they claim inhibit their ability to stand watch at an optimum level. His research focused on answering questions related to environmental constraints and time in service as factors related to sleep and fatigue. LT Gamboa also presented a useful discussion regarding the importance of sleep management in optimizing operational performance. His conclusions emphasize the requirement to manage sleep as a resource for warfighters. He says the potential for mismanaged sleep could most certainly result in missions being compromised (Gamboa, 2002).

D. MEASUREMENT TOOLS AND SOFTWARE USED IN NPS STUDIES

The specific measurement techniques and tools used in recent NPS fatigue and performance studies are described in the following paragraphs. The particular WAM device used is called an Actigraph. It was developed by the Precision Control Design, Inc. (PDC). The sleep watches, along with accompanying software to initialize and download the data, are marketed by Ambulatory Monitoring, Inc. (AMI). Dr. Timothy Elsmore from Activity Research Services, Inc. has authored the Action-W software (marketed by AMI) which is a Windows-based program used for analysis of Actigraph data. The Fatigue Avoidance Scheduling Tool (FAST), developed by NTI, Inc., was used to model the performance effectiveness of the participants based on the WAM data. Finally, ARES software used on the handheld PDA devices, developed by Dr. Timothy Elsmore, provides researchers with a performance data point based on measurements taken from tasks conducted by participants throughout the study.

1. Actigraphs and ACT Millennium Software

There are several types of commercial WAMs that monitor activity levels available on the market. NPS research teams have used the Octagonal Sleepwatch® (Sleep-O Model) Actigraph and associated Actigraph reader interface made by PDC (see Figure 3). The Actigraph contains an accelerometer that can be set to record activity in epochs varying from one second up to one minute. All Actigraphs used in NPS studies were set to collect data in one-minute epoch lengths. The ACT Millennium software is the Windows based computer program used to initialize the Actigraphs and download the data from them. The watch is placed on an Actigraph reader (shown in Figure 3) that allows communication between the ACT Millennium software and the Actigraph. Local time, type of Actigraph, sampling modes (e.g., Zero Crossing mode, Time Above Threshold mode, and Proportional Integrating Measure mode), epoch length, Actigraph identification number, when to start recording data, estimated runtime, and a header preview are all reviewed and set during initialization. ACT Millennium also has a diagnostics function that allows the research team to check the settings of the Actigraph reader and to ensure the accurate transmission of data.

Figure 3. Octagonal Sleepwatch® and Reader Interface

Figure 4 shows the ACT Millennium start up screen. ACT Millennium allows the Actigraph data to be saved with a .DAT file extension which can be read by ACT Millennium software or with the .AMI file extension that can be read by another AMI software program called Action W.

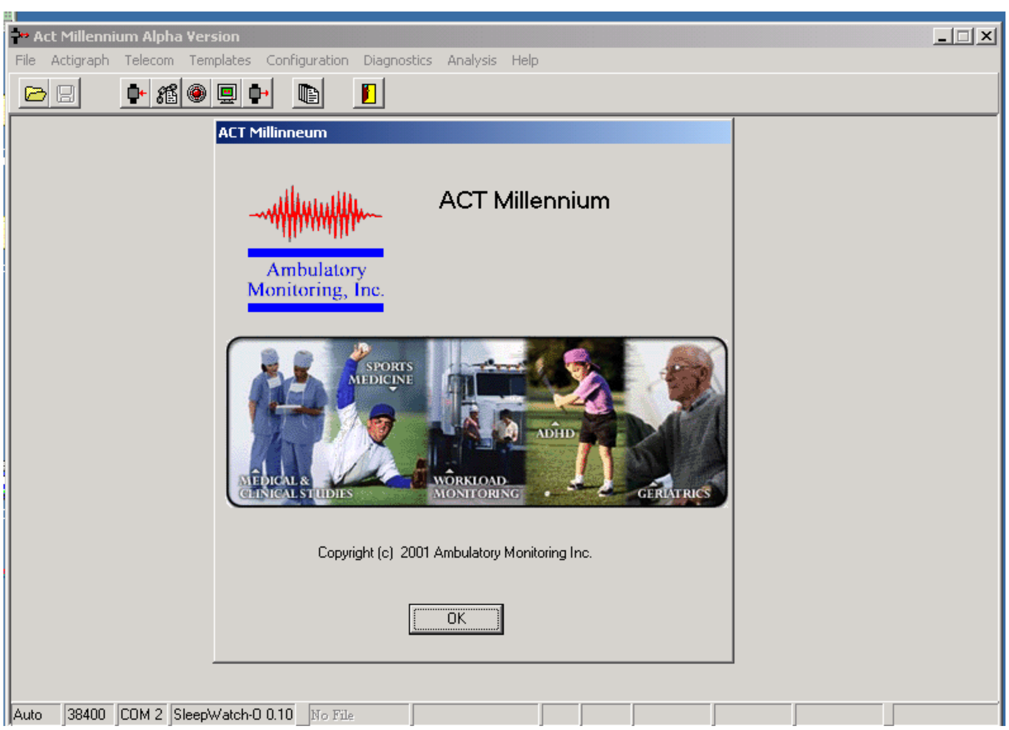

Figure 4. ACT Millennium Start Up Screen

2. Initial Processing of Actigraph Data: Action W

Ambulatory Monitoring, Inc. also markets the Action W software. Action W allows visualization of the activity levels for the entire data collection period. A screen capture of an individual's sleep data are displayed in Figure 5. Action W scores the sleep and wake periods and offers manual trimming of the data if the researcher deems it necessary. The red underline indicates sleep and the green shaded portion represents down periods. Basic statistics can be run using Action W such as total sleep minutes, wake minutes and percentages of time spent sleeping. The Cole-Kripke algorithm is used when scoring the sleep and wake periods. This method, developed in 1988 and revised in 1992, uses a weighted average of the previous four minutes, the current minute, and the next two minutes in order to determine whether the current minute should be labeled as 'sleep' or 'wake.' The researcher can code the data to override the automatic scoring of the accelerometer to allow for the correction of the more obvious discrepancies that may

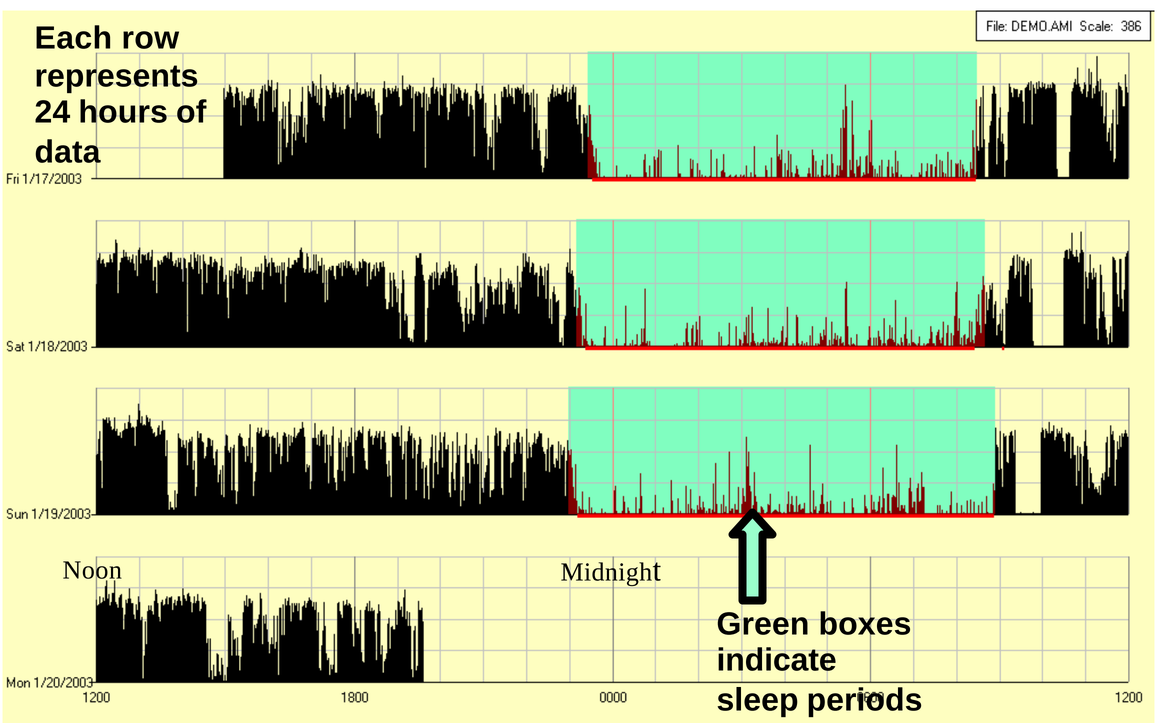

Figure 5 Action W Linear Actigraph View of Sample Individual's Data

result from using the weighted average. Action W allows the researcher to save a file with the file extension .AMI for use again in Action W or as an epoch by epoch (.EBE) format for use with FAST.

3. Fatigue Avoidance Scheduling Tool (FAST)

FAST is a computer program developed by NTI, Inc. designed to allow schedulers to estimate the effects of various schedules on human performance. It also allows WAM data to be imported into a FAST schedule. Using the Actigraph watch, for example, researchers at NPS have been able to "clean" the collected data using the Action W tool and then import that data to the FAST tool. This allows the researcher to see the modeled performance effectiveness levels of the participant throughout the course of the study. FAST gives estimates of an individual's predicted effectiveness based on the SAFTE model described earlier. It uses the SAFTE algorithm created by Dr. Steve Hursh (SAIC) in conjunction with the Walter Reed Army Institute of Research (WRAIR). The schematic of the SAFTE Model is shown in Figure 6. It integrates quantitative information about circadian rhythms in metabolic rate, cognitive performance recovery rates associated with sleep, and cognitive performance decay rates associated with wakefulness, and cognitive performance effects associated with sleep inertia (Hursh et. al, 2003). The software also allows the research team to pre-condition the starting condition for an individual to adjust for differences in sleep prior to the actual data collection period. This allows the level of the individual's sleep reservoir to be set based on more realistic conditions. FAST then analyzes each minute of data imported and graphically represents the individual's sleep efficiency.

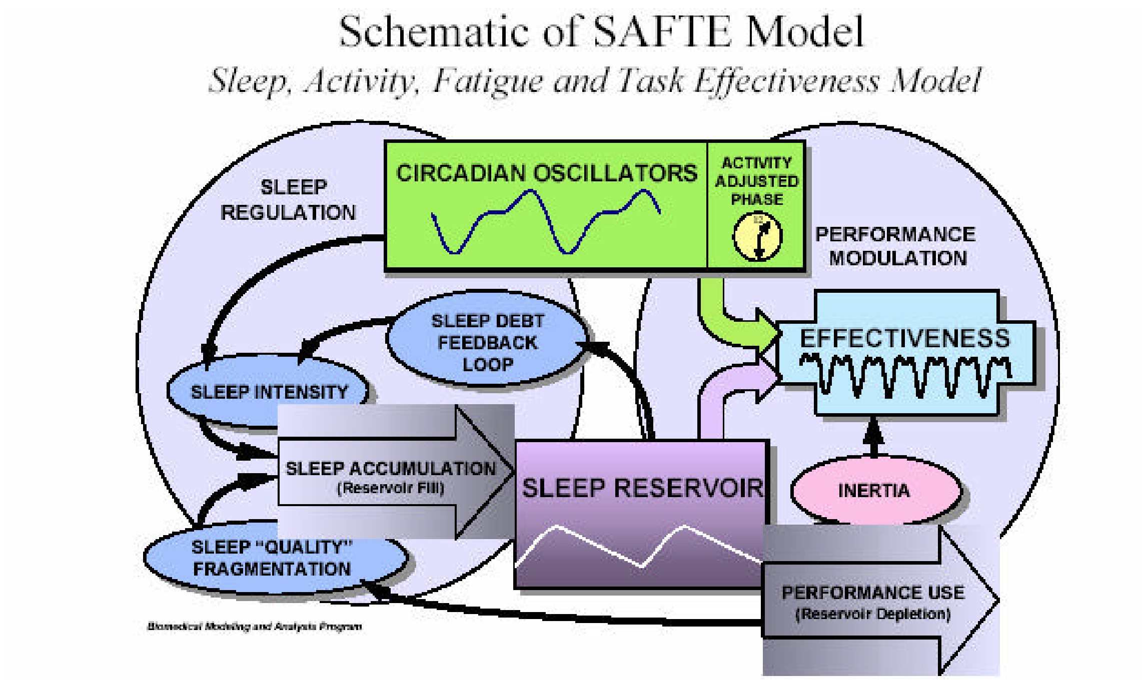

Figure 6. Schematic of the SAFTE Model (From: Hursh et. al, 2003)

A screen capture with explanation is shown in Figure 7. Sleep intervals and work periods are depicted on the horizontal axis. The vertical axis represents the effectiveness, and the right hand side shows a blood alcohol equivalent measure. The main display is shown in colors that represent degrees of effectiveness. The upper section is green indicating excellent effectiveness, followed by yellow indicating reduced effectiveness. The bottom portion is pink/red and indicates less than 65% effectiveness. A dotted line is shown at the 78% effectiveness level; a level chosen by the U.S. Air Force as the "floor" for predicted effectiveness for their pilots. Additional tools allow the researcher to view and manipulate the data in many different ways, such as minute-by-minute effectiveness or by altering start times and durations of wake periods. If the Action W data are not accurately trimmed to identify true sleep/wake periods, the FAST data will be skewed. Requiring the individual participants to maintain a log of their activity during the data collection period allows researchers to trim the collected Actigraph data efficiently. The quality of these logs may determine the accuracy of the FAST modeled outputs of performance effectiveness.

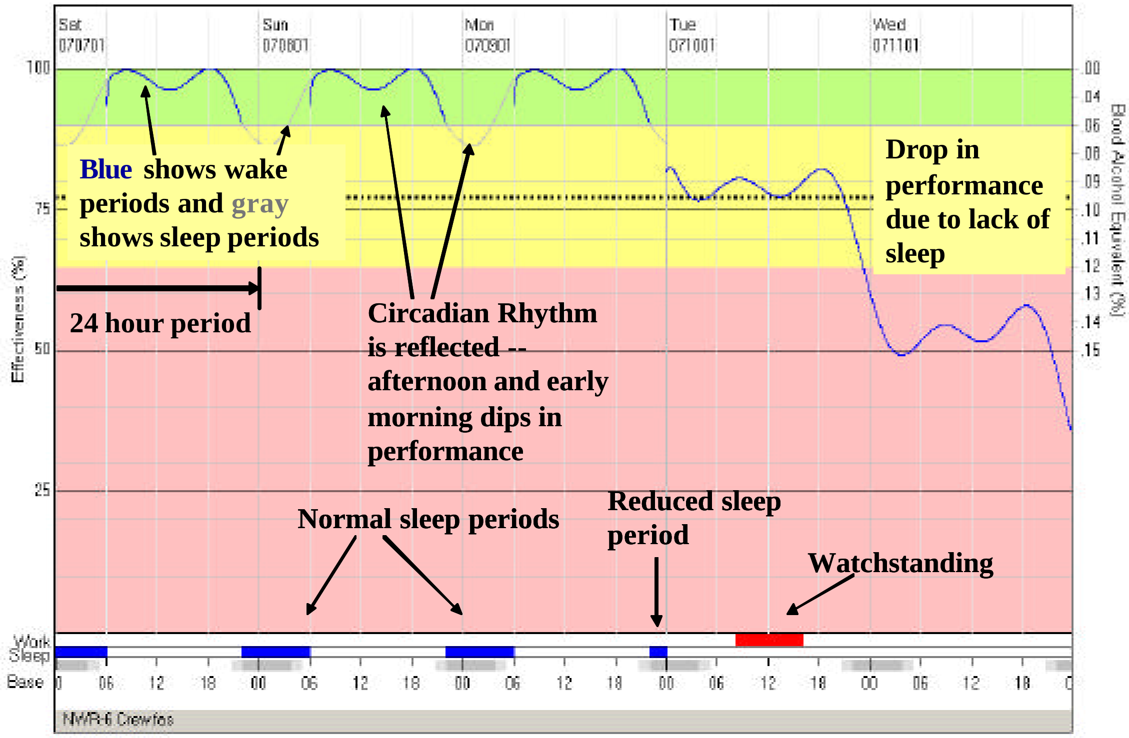

Figure 7 FAST Display

4. ARES (ANAM™ Readiness Evaluation System)

ARES is automated neuropsychological testing software for operation on handheld PDAs that use the Palm Operating System (OS) Software Version 3.5 or later that was developed by Dr. Timothy Elsmore. The system is designed to run test batteries that are intended to meet specific clinical, operational, or research goals. These tests include Sleep Scale, Mood Scale 2, Simple Reaction Time, Code Substitution (Learning), Math Processing, Matching to Sample, Logical Relations, Code Sub (Delayed Recall), and Memory Search. The ARES will operate on a wide range of PDAs including those with black and white or color displays. The start-up screen is shown in Figure 8.

Figure 8. PDA Device (Palm m100) with ARES Software

The ARES allows multiple users on a single PDA, and includes a variety of standard test batteries and a means to install custom batteries. The data saved on the PDA can be downloaded to a desktop data management program, DataMan, using a direct serial link, USB connection or wireless modems. The data can be downloaded using the HotSync Manager associated with most PDA software or by importing directly from the handheld device to the DataMan software. When using HotSync, ARES data are stored in a Palm Database (.PDB) file format which in turn can be accessed using the DataMan software. The DataMan program has limited data analysis functions and allows the data to be copied easily into Microsoft Excel or Microsoft Access tables for further analysis. The NPS Human Systems Integration Lab (HSIL) currently uses the Handspring Treo 90 as the PDA device of choice based on cost and functionality.

E. KNOWLEDGE VALUE ADDED METHODOLOGY

To evaluate the reengineered process as compared with the current process, the Knowledge Value Added (KVA) methodology was used. Developed for use in an economic setting, this KVA methodology is often used to determine the value information technology adds to a given process. Other methods of assessing value include Cost-Based Approaches, Market Approaches, Income Approaches, and Real Options Approaches. Because of the nature of this comparative analysis, it was necessary to choose a methodology that allowed a valuation for knowledge. Because revenue is not generated in these processes, a surrogate measurement was required. KVA provided the means to measure the inputs to the current process while capturing the given outputs and compare this to those of the reengineered process.

KVA is based on the principle of replication that states "given that we have the knowledge necessary to produce the change, then we have the amount of change introduced by the knowledge" (Housel and Bell, 2001). If a process input is the same as its output, there was no change, therefore, no value has been added. Representing a process as a function P(X) where P(X) = Y, it follows that if X = Y, there was no change and no value added by the process. Value is assumed to be proportionate to change. Change can be measured by the amount of knowledge required to make the change. By definition, value is proportionate to change which is proportionate to the knowledge required to make the change. To compare the current sleep study process to the reengineered process, it was necessary to measure the amount of knowledge required to produce the output of the core sub-processes and measure the cost of using this knowledge to find the Return on Knowledge (ROK) as the factor of comparison. ROK is the amount of knowledge divided by the cost. This ROK is a corporate performance ratio that gives order of magnitude comparisons for all of the processes. The amount of knowledge is determined by process analysis and interviews with subject matter experts to quantify the learning time (relative and actual) for each process. Process instructions or bits required to produce process outputs are other measurement techniques to obtain the amount of knowledge. The cost is calculated by multiplying the cost for the resource by the amount of time required to use the knowledge to produce an output. The resulting cost number is applied directly to the output for the process.

The seven step method (Housel and Bell, 2001) to find the ROK for both the current and reengineered process was used to measure how much the productivity improved using information technology from the current or "AS-IS" process to the reengineered or "TO-BE" process. The first step is to identify the core process and sub-processes. In step 2, common units of measure for learning time are established. Calculation of the learning time to execute each of the sub-processes is step 3. In step 4, the sampling time period is determined to capture a representative sample of the core process's final product or output. In step 5, the learning time for each sub-process is multiplied by the number of executions of that sub-process during the sample period to get the numerator for the ROK. Similarly, in step 6 the denominator for the ROK is determined by calculating the costs for each sub-process. In the final step, the ROK is calculated and the results are interpreted.

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III. CURRENT PROCESS FOR DATA COLLECTION AND ANALYSIS IN RECENT NPS FATIGUE STUDIES

A. OVERVIEW

Because the reengineered process for fatigue studies conducted by HSIL at NPS serves as the Proof of Concept for the data collection and storage methodology for human research in field environments, it was necessary to articulate the current or “AS-IS” process used in recent NPS fatigue studies. The Knowledge Value Added (KVA) approach to this process reengineering effort provides an objective method for measuring the amount of value a given component process adds as well as the cumulative value of the entire process. This enabled the comparative analysis of the current or “AS-IS” process to the process after reengineering efforts or the “TO-BE” process. To compare this value added, we had to calculate the Return on Knowledge (ROK) at the process and sub-process levels for both the “AS-IS” process and the reengineered or “TO-BE” process.

In this chapter, the seven step KVA process was used to determine the “AS-IS” ROK. Because the “AS-IS” model is a reflection of the current process used by HSIL at NPS, summaries of the techniques used in two recent NPS studies are provided to lay the foundation for the “AS-IS” model development. A review of the seven step process is described and then applied to determine the ROK for the “AS-IS” process. Finally, an assessment of the KVA analysis results follows with the identification of the focus areas for the reengineering effort, revised data collection and storage methodologies.

B. RECENT NPS FATIGUE STUDIES

Two recent studies conducted by NPS thesis students included the U.S. Navy Recruit Training Command at Great Lakes, IL (NTCGL) Study (Baldus, 2002) and the USS JOHN C. STENNIS Study (Nguyen, 2002). While the objectives of these studies differed, the methods used for data collection were similar. In both studies, Actigraph watches were used to monitor participants’ activity levels while other data were collected on the participants. In the Great Lakes study, recruit test scores, demographic and other data were collected via various databases through local points of contact at Great Lakes, Naval Training Center (Baldus, 2002). Similarly, in the USS JOHN C. STENNIS study, demographic data and data from a morningness/eveningness survey (Nguyen, 2002) were collected. To collect his information, LT Nguyen provided paper surveys for his participants to complete. In addition, the USS JOHN C. STENNIS study participants were instructed to maintain daily paper journals to record their sleep behavior as well as to record their oral temperature readings. In the Great Lakes study, no journals or logs were maintained by the participants. Because of the operational environments of these two studies, the researchers wanted to minimize the obtrusiveness of their data collection and as a result, made every effort to mitigate the burden on participants while optimizing the data collected.

The data collection methodology for both of these studies required a tremendous amount of human intervention by the researcher. After the time consuming effort involved in transposing data from manual pen and paper entries from the USS JOHN C. STENNIS participants and the printed data sheets from the Great Lakes participants to electronic MS Excel spreadsheets, many hours were spent cleaning the data. Because the data from the USS JOHN C. STENNIS study were collected and recorded before the start of the Great Lakes study, the lack of confidence in participants' ability to maintain accurate logs under operational constraints drove LT Baldus' decision to exclude participants from recording daily activity. Additional variables were of interest to both researchers but the uncertainty of the collection methods prevented their inclusion in the studies. For example, both researchers had desires to collect performance data but had no feasible means to do so. While performance testing methods were available, the unfamiliar logistics involved in using a viable collection method was a major obstacle preventing the researchers from collecting performance data.

C. KVA METHODOLOGY: THE SEVEN STEP APPROACH TO DETERMINING RETURN ON KNOWLEDGE

In the audit of the "AS-IS" process, we evaluated the Return on Knowledge (ROK) at the process and sub-process levels. To determine ROK, we measured learning time and cost. Learning time was used as a surrogate to measure knowledge embedded in the processes. Learning time is the amount of time it would take for someone to learn how to do each activity in the process. The cost refers to how much money is required to use this knowledge each time the process or sub-processes are executed. After gathering the learning time and cost information, the Return on Knowledge (ROK) was calculated.

The following seven-step methodology measures processes in terms of their ROK.

STEP 1: Identify the core process and its component processes

STEP 2: Establish common units to measure learning time

STEP 3: Calculate learning time to execute each component process

STEP 4: Designate a time period long enough to capture a representative sample of the organization's final product/service outputs following common statistical sampling practices

STEP 5: Multiply the learning time for each component process by the number of times the component executes during the sample period

STEP 6: Calculate the total cost to produce the output for each component

STEP 7: Compute the ROK for each component process

Since this method relies on the estimations of Subject Matter Experts (SMEs) for process learning time to gain a high-level ROK assessment of a given process, it is often useful to use another surrogate for knowledge such as process instructions to ensure validity of the analysis. In this Proof of Concept effort, we consulted with the SMEs and developed a process model using actual learning times for each sub-process. The granularity of this effort provided sufficient evidence to the stakeholders at NPS that further assessments were not required. The same level of granularity was applied to the reengineered "TO-BE" process allowing viable comparisons to be made.

D. CURRENT PROCESS MODEL

To clearly represent the process model for the past NPS fatigue research studies, we interviewed Dr. Nita Miller, head of the Human Systems Integration Lab (HSIL) at NPS, and several of her thesis students who have conducted data collection and analysis for fatigue studies. Additional interviews were conducted with other DoD SMEs who are involved in similar processes of collection and analysis. Observations of the NPS researchers were also recorded during the latest studies to allow the creation of a representative model of the "AS-IS" process. Applying STEP 1 of the seven step KVA methodology, the core process of Conducting a Fatigue Research Study was identified. Three basic phases were determined as sub-processes of the model: 1) Collect Data, 2) Prepare Data for Analysis, and 3) Analyze and Publish Data.

1. Collect Data Sub-Process

In the Collect Data Sub-Process shown in Figure 9 below, the activities are depicted with circles while the outputs of those activities (or processes) are indicated by squares. The sub-process begins with a requirement for research resulting in a request for the HSIL to conduct a study. Included in this input request are the study parameters: purpose of the study, permission for study from customer requesting research, identification of the research team, and methods of data collection. Because the model for NPS research centers on students collecting and analyzing the data, training of the research team is essential for each study conducted. This Train Research Team Activity focuses on teaching research methods to the research team and includes instruction on study design, methods of data collection and analysis, and other unique considerations of conducting human research in operational environments. The output of the activity is a Trained Research Team.

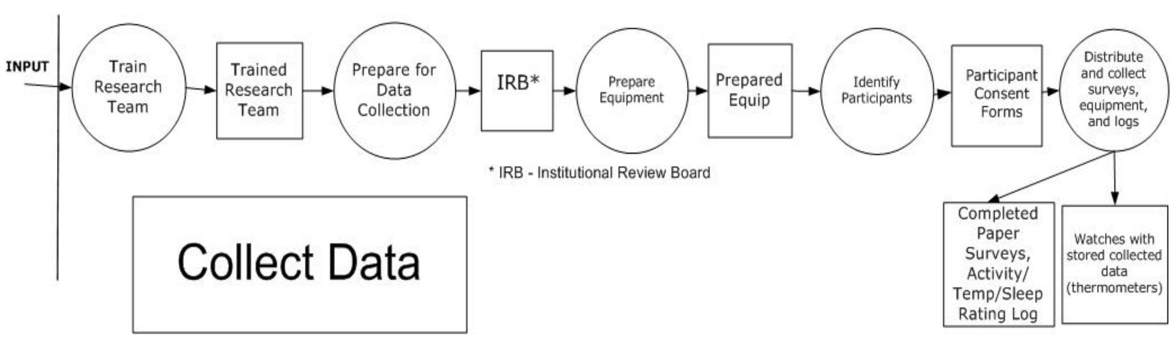

Figure 9. Collect Data Sub-Process

The next phase of this sub-process is to define the conditions under which the data will be collected. Under the Preparing for Data Collection Activity, there are several tasks required including:

- Design the Study
- Identify Funding Requirements
- Create Demographic Survey
- Type Lark and Owl Survey
- Create Activity/Temp/Sleep Rating Log
- Type Consent Forms
- Produce Institutional Review Board Proposal

The output documents from these tasks are the completed study design, approved Institutional Review Board Proposal, funding requirements, typed surveys, logs, and consent forms.

Just before data collection actually starts, the required equipment which is to be used in the collection is prepared. The tasks for this Prepare Equipment Activity include initializing the Actigraphs, obtaining thermometers when participants' temperatures will be recorded, and making copies of all surveys and forms for all participants. The output is all of the paperwork and equipment prepared for collection. Once on location, the research team then has to identify the study participants. Because of operational constraints, pure random sampling is almost never an option but the researchers try to select a sample of participants that will be representative of the entire group. Once selected, the participants fill out consent forms enabling the research team to conduct the study.

The next activity, Distribute and Collect Surveys, Equipment, and Logs, includes both issuing the equipment and the instructions required of the participants as well as the collection of the equipment upon completion of the data collection phase. The output of these tasks includes the surveys and logs completed by participants as well as the Actigraphs with recorded actigraphy in their memory, and the thermometers. Once all equipment and data are collected, the Collect Data Sub-Process is complete.

2. Prepare Data for Analysis Sub-Process

With the collected equipment, paper surveys, and logs, the research team returns to HSIL at NPS and begins the Prepare Data for Analysis Sub-Process represented in Figure 10. The inputs to this sub-process come from the Data Collection Sub-Process outputs e.g., Actigraphs with recorded data and completed surveys and logs.

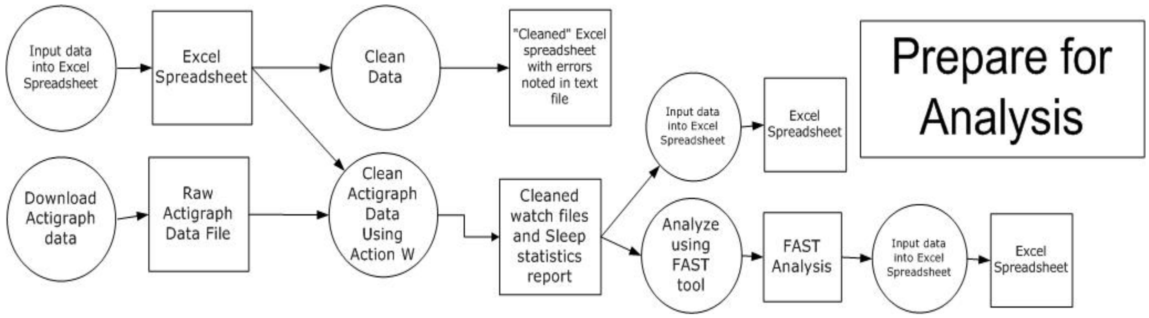

Figure 10. Prepare Data for Analysis

The first activities of this sub-process include transferring the data from the Actigraphs and paper recordings to an electronic format that allows the researcher to then "clean" the raw data. The data from the paper surveys and logs must be manually input to a Microsoft (MS) Excel spreadsheet. The data from the sleep watches has to be downloaded to a computer using the Actigraph, the Actigraph Interface Unit, and Act Millennium software. Data from each Actigraph are saved with the file extensions .DAT (Act Millennium Data format) and .AMI (AMI without Application format) for use with the Action W software. Once these raw data files have been established, the next activities include "cleaning" the data.

The data from surveys and logs have to be checked manually for data entry errors. Additionally, the quality of the logs maintained by the participants is determined by the researchers. The participants often forget to record their data or become so overwhelmed with operational events that their logs are often incomplete or inaccurately filled out. If there are too many errors and they cannot be rectified, researchers may have to remove an entire participant's data set from the study. Additionally, the tedious nature of manually entering data from paper journals to electronic media often requires the research team to review the data entries several times to ensure accuracy.

The Actigraph raw data are imported to the Action W software. Based on the algorithm for sleep scoring activity level, Action W automatically codes the Actigraph's recorded activity epochs as sleep or wake episodes. An example of raw data of a participant that has been automatically coded by Action W software is shown in Figure 11. The coded data are compared with the sleep/wake log of the participant. If there are discrepancies, the researcher has to determine the best code for the data. This subjectivity is necessary to overcome limitations of the equipment.

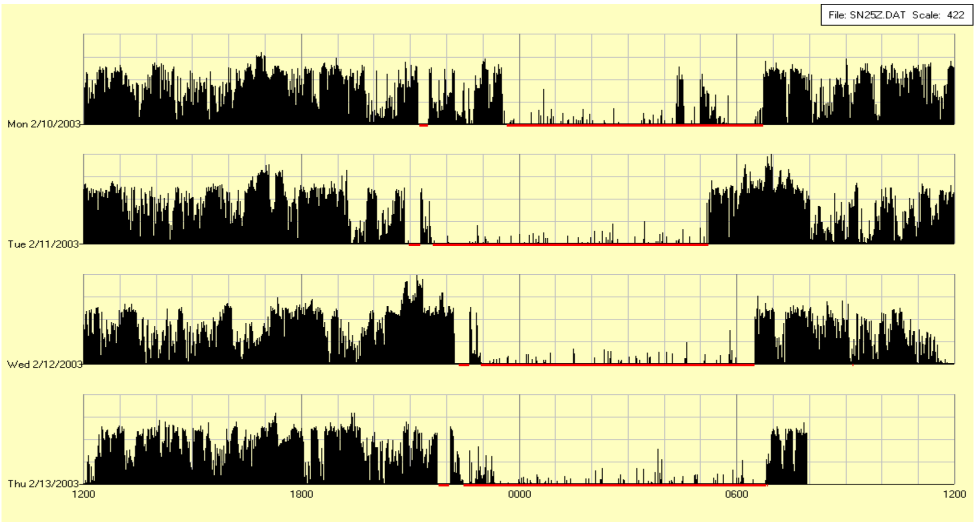

Figure 11. Automatically Scored WAM Data Using Action W

In this example, the participant logged that he had taken off his WAM for a shower during the times circled in Figure 12. Because the activity levels are at or near zero, the Action W scores these periods as sleep epochs (indicated by the red line beneath the recorded time periods).

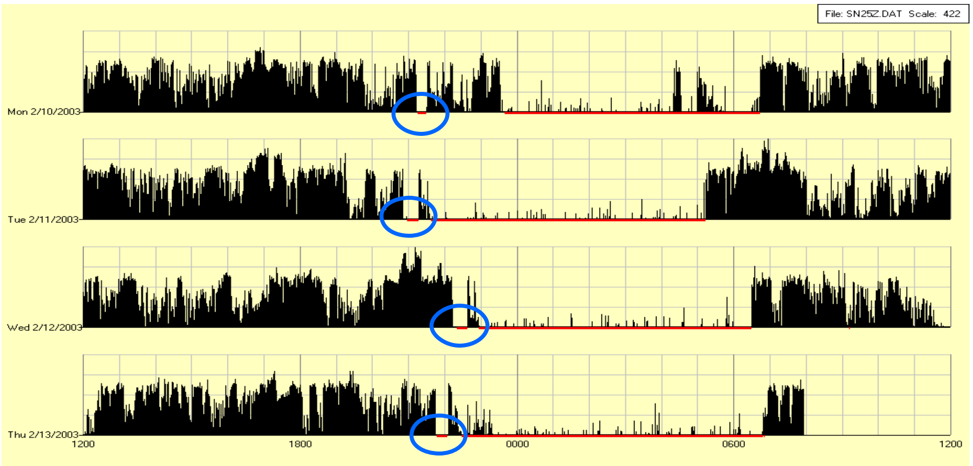

Figure 12. Circled Times the Participant Removed His Actigraph for Showers

The researcher can manually recode these epochs as sleep, as shown in Figure 13, to allow more a more accurate depiction of the participant's behavior. Once "cleaned," the file is saved with file extensions .AMI (for reuse with Action W) and as .EBE (epoch by epoch for use with the FAST software). Any data that had been corrupted due to mechanical or human errors are also identified and may be removed from the study altogether. Action W also calculates sleep statistics for each data file. The output products of this activity are the data files themselves, the statistics reports for each participant and the MS Excel spreadsheets with recorded survey and log data.

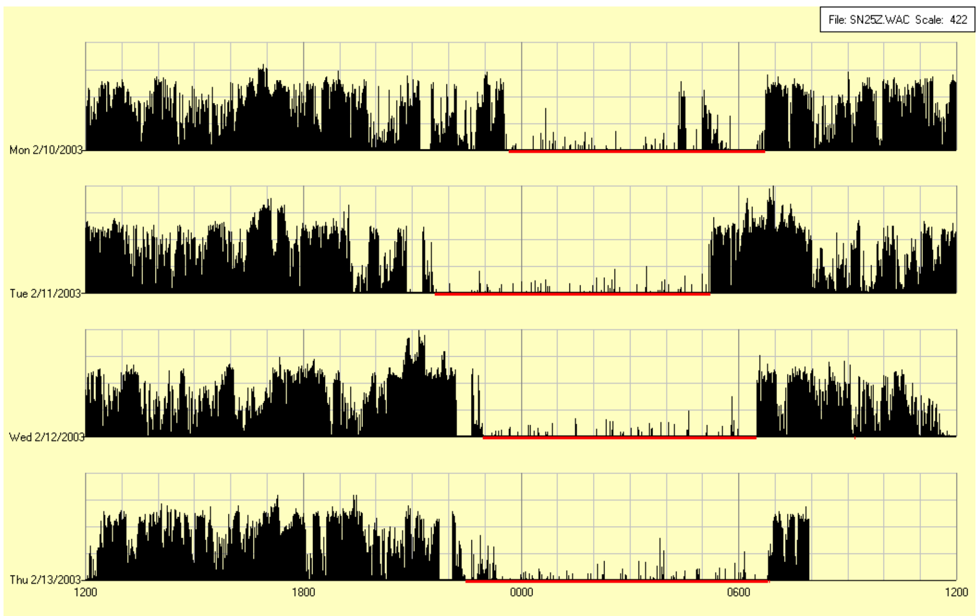

Figure 13. Manually Recoded Shower Times as Wake Epochs

The Actigraph data are then processed in two ways. First, the researcher exports the sleep statistics from the Action W data files into a MS Excel spreadsheet and manually manipulates these into a format compatible with data analysis tools for use at a later stage in the process. The second way the data are processed is using the FAST modeling tool. The researcher sets up a schedule encompassing the period of the study and pre-conditions the three previous days of the data collection period to match a realistic sleep/wake cycle of the participant. If enough data were collected, the researcher can use the first three days of collected data to automatically set the pre-conditions for the participant. Once a FAST schedule is defined, the researcher imports the .EBE Actigraph file of each participant to this schedule and is able to model the performance effectiveness during the period of the study. The researcher compares the FAST analysis to the logs and surveys to identify correlations. Any required data from the FAST models are recorded in MS Excel spreadsheets to allow for further data analysis by the researcher. The outputs of this sub-process include all Action W sleep/wake periods screen captures, FAST performance effectiveness model screen captures, as well as the "cleaned" MS Excel spreadsheets prepared for export to data analysis tools.

3. Analyze and Publish Sub-Process

The data from the previous sub-process are analyzed and the comprehensive analysis is published in the Analyze and Publish Sub-Process shown in Figure 14. The "cleaned" data are analyzed using MS Excel tools as well as exported to SPSS (statistical software package used by HSIL researchers) for further analysis. Once in SPSS, the data have to be properly formatted for analysis. The output of the analysis includes the results of various statistical tests performed on the data in the form of tables and graphs. The research team then combines all of their efforts and writes their thesis using the outputs of these analysis tools and the outputs from other sub-processes. The final output of the whole fatigue study process is the published thesis where conclusions are drawn based on the analysis conducted.

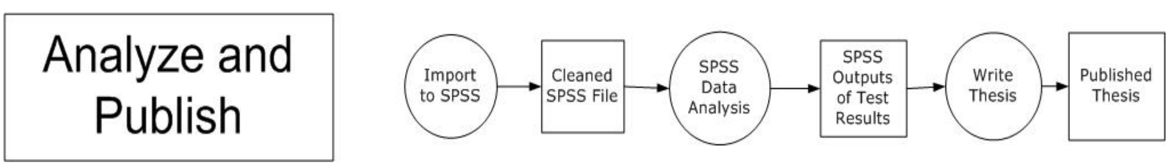

Figure 14. Analyze and Publish Sub-Process

E. RETURN ON KNOWLEDGE FOR "AS-IS" PROCESS USING KVA ANALYSIS

In order to compare the current process with any newly engineered process, a framework of comparison has to be established. Using the KVA methodology, we are able to calculate a ROK (Return on Knowledge) of the current sub-processes in terms that we can compare with the reengineered process. Additionally, KVA allows us to identify the shortcomings of the current process. The numerator in the ROK ratio is the total amount of learning time required to execute a process. The denominator is the cost of executing the process (or firing that knowledge). A summary of the core process and sub-processes identified in STEP 1 are shown in Figure 15. Following STEP 2, the common units used to calculate for learning time in hours were established. The number of hours required to learn to execute each task was calculated as part of STEP 3. Where applicable, the learning time of associated IT products when used in the execution of the task was also added to the total learning time. Following STEP 4, the representative sampling time period was determined to be one year. To determine the weighted learning time for each sub-process according to STEP 5, the learning time required for one execution of each task was determined through interviews with SMEs.

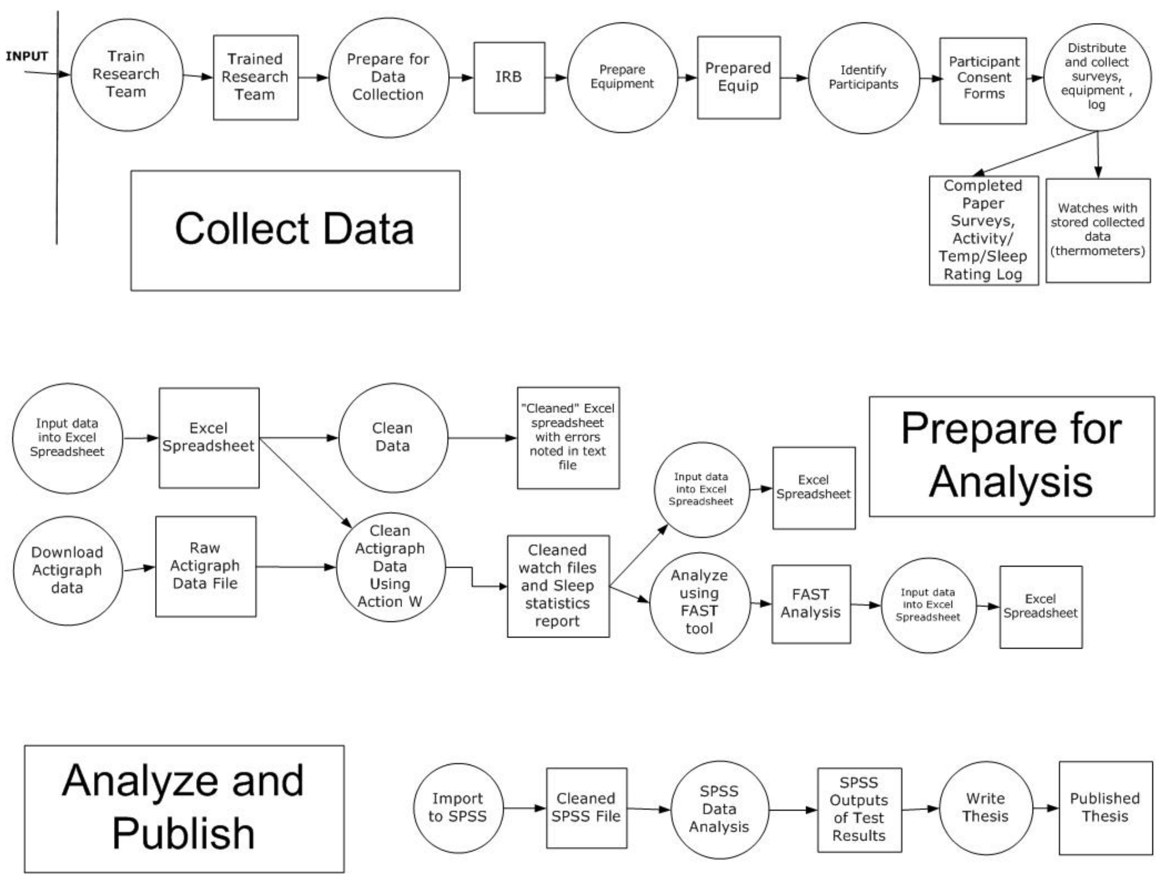

Figure 15. "AS-IS" Process

Some tasks were executed more than one time. For example, when preparing equipment for the study, the task of initializing the Actigraph watch had to be repeated for every participant on the study. If the task was executed more than one time, then the knowledge for that task fired more than one time. The number of times the knowledge was fired in the given sample period is referred to as the weighted learning time. In the NPS studies, the average number of studies completed in each sample period of one year was one and the average number of participants identified for a study was 25. However, due to human and equipment errors, the SMEs estimated that on average 20% of data from the participants were not usable in the study. In other words, the average number of participants with adequate data was estimated to be 20 per study. The weighted learning time is only calculated for the amount of successful executions of the tasks. Therefore, in a task such as initializing the Actigraphs, the learning time for one execution of the task was multiplied by 20 (the number of successful executions) to get the weighted learning time for the task. After all of the weighted learning times for each task were calculated, they were added together for a cumulative learning time in hours for the activity. Correspondingly, the total learning times for each of the activities were added together representing the total learning time for the sub-process. In STEP 6, the cost to execute each task was calculated. The hourly wage of the researcher was conservatively estimated at $22 (based on the annual base pay of an O-3 in the active service). The cycle time or the amount of time for the researcher to execute the task was calculated. Because the cost included the total number of times the task was executed, the cost for the task included the times the task was executed but the data was not used. For example, if the researcher had to initialize 25 Actigraphs, the cost calculated for the task was the cycle time to initialize an Actigraph multiplied by 25 watches. After the cost for each task was determined, the total cost for each activity was calculated by adding the cost for each task. Similarly, the total cost for each sub-process was then calculated by adding the total costs of each activity included in this sub-process. To determine the ROK according to STEP 7, the ratio of weighted learning time divided by cost was calculated. A summary of the calculated weighted learning times and total costs to produce the ROK for each sub-process is shown in Table 1. (For a comprehensive table of calculations by task, see Appendix A.) At NPS, these research studies are conducted by students working under a principle investigator/professor. As a result, the ability to maintain corporate knowledge is extremely difficult. Once a student becomes familiar with how to complete the tasks, he graduates resulting in a loss of knowledge he acquired while executing the tasks for the study. Because of this major factor, the ROK of the whole process is inherently low. The reengineering effort is critical to try to streamline the process to make it as efficient as possible but also to try to capture some of the knowledge in IT tools that allow NPS to maintain some of the corporate knowledge they are continually losing. It is imperative to find a reengineered process that will cost less and provide greater return.

Sub Processes	Weighted Learning Time (Hrs)	Total Cost ($)	As-Is ROK
Collect Data	289	3300	8.76%
Prepare for Analysis	1158	8277.5	13.99%
Analyze and Publish	1161	10192	11.39%
TOTAL	2608	21769.5	11.98%

Table 1. "AS-IS" ROK

F. AREAS TO FOCUS REENGINEERING EFFORT

Looking at the ROK for each sub-process at the activity and task level, some tasks were clearly identified as providing low return on knowledge. After consultation with the SMEs, the data collection and data storage areas of the process caused the greatest concern. The data collection methods of the "AS-IS" process are tedious and error prone. The paper logs and surveys are a hindrance to participants based on exit surveys from the recent fatigue studies. The paper entries are a source of a tremendous amount of additional work. Requiring the participants to enter the data once on paper and then the researcher to transfer the same data to a spreadsheet is an example of the inefficiency inherent in this process. The extra time required to diligently "clean" the data by comparing the paper entries to the computer entries demonstrates little Return on Knowledge. The conservative estimate of a 20% loss of collected data due to the combination of human and mechanical errors appears unacceptably high and avoidable. Additionally, the lack of data storage capability is a significant drawback of the current process. While Dr. Miller is involved as an advisor in all of the studies conducted by HSIL, each researcher determines how he saves his data for data analysis. Because of the disparate ways of storage, the effective result is that the published thesis is the only source of storage of collected data. To use this for future studies or conduct any meta-analysis is virtually impossible given the cost required to do so. Considering the particular areas of low ROK in the "AS-IS" model, Figure 16 highlights the particular activities targeted in the reengineering effort.

After analyzing the ROK for each task and discussing the complexities of each with the subject matter experts, the focus of the reengineering effort became clear: streamlining the data collection process and storing data for future use.

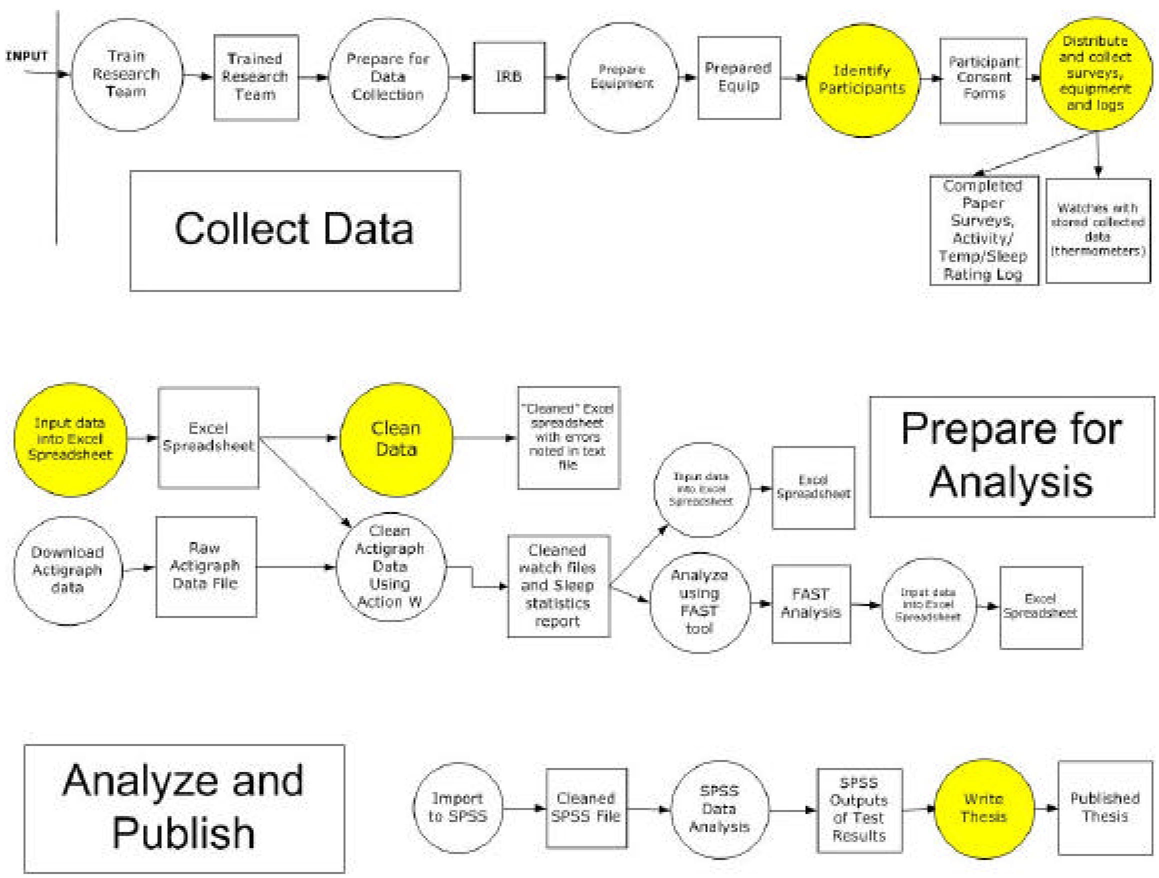

Figure 16. Areas of Focus for Reengineering Effort

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IV. REENGINEERING THE PROCESS

A. OVERVIEW

The reengineering effort of this thesis centered around creating a data repository and streamlining the data collection methods using current information technology. The research teams that conduct the human performance and fatigue research at NPS are typically thesis students working towards a Master's Degree in Operations Research. While their knowledge of data analysis software is extensive, their experience with web-page design, web servers and databases is often limited. Therefore, the technology inserted into the "TO-BE" process had to be relatively easy for the researchers to learn while still maintaining the desired effect of streamlining the process. Also, the software and hardware we selected for any IT implementation had to be easily supportable. We did not want the Human Systems Integration Lab to become dependent on a specific vendor where costs to maintain the software became unreasonably high or proprietary issues would cause expensive upgrades. Every attempt was made to use IT assets that were either non-proprietary or that was supported by the IT staff at NPS. This chapter includes a consolidation of the Planning, Requirement Analysis, Design and Implementation Phases of the Study Repository Template database system development as well as the data collection technique development. A summary of the database design created in Microsoft Access 2002 and the collection methods including the automated daily log created using HanDBase 3.0 and the web-based survey forms created using Microsoft FrontPage 2002 are included in the Implementation Phase.

B. PLANNING (SURVEY) PHASE

After extensive study of the "AS-IS" process, we targeted our reengineering efforts to achieve two main goals. First, we wanted to allow participants and researchers to be able to easily record data with simple and standard data collection methods. Secondly, we wanted to provide the HSIL with a data storage capability that brought standardization to the fatigue studies. Along with both of these goals, we also wanted to afford researchers the ability to easily adapt the collection and storage means to suit the unique requirement demands for each study. In the planning phase, we refined these goals to prepare for the design and implementation of IT solutions to enhance the "TO-BE" process.

1. Problem and Scope

Our challenge was to develop a database and data collection techniques to facilitate efficient and timely data analysis for operational fatigue studies in an automated setting which can be implemented by future fatigue research teams from the HSIL at NPS. Addressing these issues, we used a three tiered architecture approach to data collection and storage in the reengineering process: a user interface layer, a database layer and a web-server layer. The graphical user interface layer allows data to be entered into and extracted from the database layer. Because both study participants and researchers required access to the databases, it was important to keep the graphical user interfaces simple and self explanatory. By automating the data entry, the research teams can eliminate the task of transposing data from paper surveys to electronic spreadsheets thus reducing the number of errors. The database layer provides flexibility and efficiency for data storage. Additionally, a template database provides the HSIL researchers with a method of standardization to maintain data from all fatigue studies that currently does not exist. The web-server enables participants to have the ability to enter data using the web while giving researchers the ability to access data from many studies from a single storage area. Templates of survey designs from data collection techniques as well as the database template stored on the web-server provide institutional knowledge from which each research team can build and subsequently add. The following description summarizes the automated functions required of the system. The system:

- Enables a research team to record the parameters of a study including information such as duration, location and a summary of the study;
- Allows participants to enter survey data via the web prior to the start of the study to allow the research team to prepare necessary equipment and paperwork for the study ahead of time as well as conduct preliminary analysis of participants prior to the study;
- Facilitates the preparation of the equipment by enabling research teams the ability to maintain calibration and initialization status of the equipment as it is prepared for use in a field study;

- Provides the capability for the researcher to assign equipment to participants by serial number and track status of collected equipment and data after the data collection portion of the study is finished;
- Enables participants to log daily events easily without hindering them in their operational settings;
- Provides a means to collect performance testing data from participants in an unobtrusive manner;
- Provides the flexibility to easily change or expand data collection requirements to accommodate researchers when different or additional data variables must be collected; and
- Supplies the HSIL research teams at NPS with standardized templates for data collection and storage methods, expanding and retaining their corporate knowledge.

2. Constraints

Though each study conducted by HSIL has unique requirements, the prototype system is designed as a template which a research team can easily tailor to suit their particular study's requirements. The participant surveys for this system include a Demographic Survey template providing information about the individual participant and a Lark and Owl Survey based on the morningness/eveningness scale included in APPENDIX B. The template also includes the capability to collect performance data on participants using the ARES software designed for use on the PDA. Finally, an event log template was created from a software database development package.

C. REQUIREMENTS ANALYSIS PHASE

1. Methods of Data Collection

Survey input forms were required to collect survey data from participants via the web. Many web-page design software packages were evaluated including non-proprietary software. Because the research teams from the HSIL generally have little to no web design skills, it was important to choose software that was relatively simple to use and supported by NPS IT staff. Microsoft FrontPage is easy to use and classes are routinely offered by NPS IT staff for Microsoft FrontPage. Also, the software is available through the NPS academic use license so no additional costs for the HSIL are incurred. The template design includes a generic Demographic Survey and a standardized Lark and Owl Survey.

To maintain equipment statuses and to simplify the assignment of equipment to participants, data input forms for the researchers to use were also required. In addition, the SMEs articulated a tracking requirement for maintaining a record of when assigned equipment from a participant was collected and when data from a participant had been successfully downloaded to the database. A form allowing researchers to track their work progress was needed to fulfill this requirement. Because of the pressures on researchers conducting a field study, an effort was made to standardize the data collection processes to alleviate some of their administrative burdens.

In order to efficiently "clean" participants' Actigraph data and analyze participants' behavior with respect to their work schedules, it is imperative for researchers to be able to view a daily event log from participants. The information collected on this log includes events such as when a participant removed his Actigraph, when he went down for sleep, when he awoke and when he started and ended a work shift. Because these events are logged throughout the day, using a PDA to record these events provides an unobtrusive means for data collection.

ARES performance testing software for PDAs was used. The data collected from each test a participant takes are stored in a file on the PDA and can be downloaded directly into the accompanying Data Manager software for ARES data or stored on the PC using the HotSync function and later imported to the Data Manager software. Once opened in Data Manager, the data can be copied to a MS Excel spreadsheet for analysis.

2. Conceptual Data Model for the Database

After the thorough analysis of the current process, we gained a comprehensive understanding of the data required for collection and the processes involved in using particular data for analysis. Through SME interviews, we also gleaned information regarding the potential future uses for the data to ensure we incorporated into the storage facility all pertinent information for a particular study. The subsequent paragraphs describe the requirements for the database design.

a. Entity Description

After clarifying the data requirements, the following entities were modeled: STUDY, RESEARCH TEAM, PARTICIPANT, ACTIGRAPH, PDA, LOG, ARES DATA, LARK AND OWL, ACTGRAPH STATUS, PDA STATUS, and COLLECTED EQUIPMENT AND DATA. The attributes for each of these were clearly defined. The ARES DATA attributes include those defined by the ARES performance testing software designed for the PDA. The attributes for the LARK AND OWL are based on the standardized morningness/eveningness scale in Appendix B. The following lists these attributes for each entity:

PARTICIPANT
Study ID
ParticipantID
LastName
FirstName
MiddleInitial
Rank
Prior
Specialty
EmailAddress
PhoneNumber
DSN
PagerNumber
OfficeAddress
City
State
Age
Gender

STUDY
Study ID
Study_Name
Study_Description
Study_Begin_Date
Study_End_Date
Study_Duration
Study_Location
Number_Participants

ARES DATA*
Record
Subject
Test
Session
PIndex
Rep
TestVer
Battery
BatVer
AresVer
Seed
Start
Dur
Stim
Cor
Err
Imp
Lap
ITI

*NOTE: The list of attributes for ARES is truncated. In the completed database, all attributes as they appear in the DataMan software package are included.

PDA STATUS
PDA ID
ARES Loaded
HanDBase Loaded
Log Database Loaded

ACTIGRAPH
ActigraphID
ParticipantID
Lastname

PDA
PDAID
ParticipantID
Lastname

LOG
RecordID
ParticipantID
Date
Time
Event
Note

RESEARCH TEAM
ResearcherID
LastName
FirstName
MiddleInitial
Title_Rank
EmailAddress
PhoneNumber
PagerNumber
OfficeAddress
City
State

LARK AND OWL
Lark and Owl ID
Participant ID
LastName
Up_later_than_planned
Bed_Time_No_Commitments
Early_Exercise
Evening_Tiredness
Choose_Own_Working_Hours
Self_Consideration
Total
Lark or Owl

ACTIGRAPH STATUS
Actigraph ID
Battery Last Changed
TimeStamp

COLLECTED EQUIPMENT AND DATA
Lastname
ParticipantID
Consent Forms Signed
Collected Actigraph
Collected PDA

b. *Database Perspectives*

The entities can be described using a main success scenario as follows:

- A request to the HSIL at NPS for a fatigue study defines the study parameters. The RESEARCH TEAM is formed and contact information is collected on them. The researchers then record the STUDY parameters and coordinate with the sponsoring organization to identify PARTICIPANTs.
- PARTICIPANTs complete the Demographic Survey and the LARK AND OWL survey via web input forms.
- The RESEARCH TEAM updates the ACTIGRAPH STATUS and PDA STATUS and assigns ACTIGRAPHs and PDAs to PARTICIPANTs.
- The RESEARCH TEAM prepares necessary consent forms and bundles equipment for issue. Once at the location of the STUDY, the RESEARCH TEAM issues the equipment (ACTIGRAPHs and PDAs).
- PARTICIPANTs wear the ACTIGRAPH watches and use the PDA to LOG daily events and to take ARES performance tests according to the prescribed schedule.
- The RESEARCH TEAM collects the equipment and downloads the ACTIGRAPH data using the Act Millennium software. They also download the ARES DATA and the LOG data using the HotSync function on the PDAs and then copy this data to the ARES DATA and LOG tables. The COLLECTED EQUIPMENT AND DATA are updated to ensure all equipment is accounted for and all available data have been collected from the PDAs as well as the ACTIGRAPHs for each PARTICIPANT.
- A LOG report is generated to simplify the coding of actigraphy and the analysis of PARTICIPANT behavior and performance.

c. *Design Methodology*

Through analysis of the current process, we were able to determine which data researchers sought to gain from the data collection phase in order to complete their data analysis. Our goal was to reverse-engineer the database system from a bottom-up perspective. We collected potential attributes including those already defined by surveys, the PDA log and performance testing software, linked them to entities, and then worked to resolve the relationships between them.

3. Process Data Model

Using web forms generated with Microsoft FrontPage, the PDA Event Log, PDA ARES testing software as well as forms and reports within the DBMS system, the following are the system components.

a. Data Input

- Create/modify/delete a RESEARCH TEAM.
- Create/modify/delete a STUDY.
- Create/modify/delete a PARTICIPANT.
- Create/modify/delete LOG events.
- Create/modify/delete ARES data.
- Track ACTIGRAPH STATUS.
- Track PDA STATUS.
- Track COLLECTED EQUIPMENT AND DATA.

b. Data Maintenance

- Update ACTIGRAPH STATUS.
- Update PDA STATUS.
- ASSIGN PDAs.
- ASSIGN ACTIGRAPHs.
- Update COLLECTED EQUIPMENT AND DATA.

c. Reports

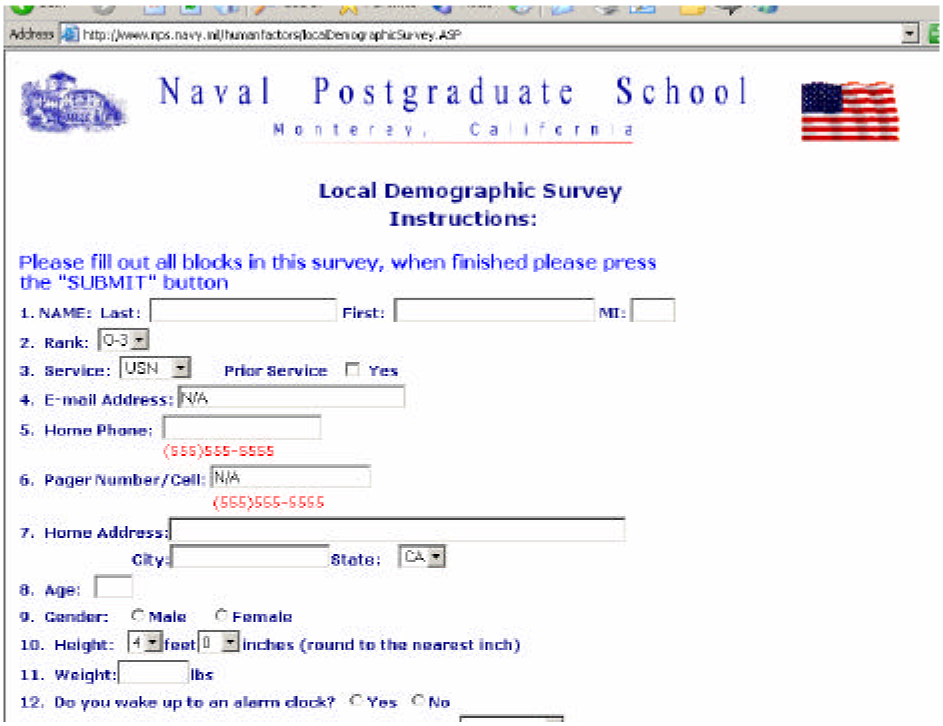
- Prepare Participant Information Report to assist Research Team with preliminary data analysis.
- Prepare Assigned Actigraph and Assigned PDA Reports to assist Research Team in tracking equipment.
- Prepare Actigraph Sign-Out Report to assist Research Team with maintaining property accountability.
- Prepare formatted Log Report to facilitate "cleaning" Actigraph data and assist Research Team with data analysis.

D. DESIGN PHASE

1. Designing Data Collection Methods

a. Web Survey Designs

Securing space on the HSIL web-server, we created and saved survey templates allowing researchers the ability to make modifications to suit each study's requirements. We designed a generic Demographic Survey Form and a Lark and Owl Form using MS FrontPage 2002. Portions of each of these templates are shown in Figure 17 and Figure 18. The forms in their entirety are shown in Appendix B. MS FrontPage 2002 allowed us to save the results of the survey to a database on the server. The two databases based on these two surveys, Demographic and Lark and Owl databases, would accumulate the survey results from each participant's submission of the data. Because the storage database is also on the server, we were able to update this survey information into the main Study Repository Template Database with a simple update query function added to the start up of the database.



Address http://www.nps.navy.mil/humanfactors/localDemographicSurvey.ASP

Naval Postgraduate School

Monterey, California

Local Demographic Survey

Instructions:

Please fill out all blocks in this survey, when finished please press the "SUBMIT" button

1. NAME: Last: First: MI:

2. Rank: O-3

3. Service: USN Prior Service Yes

4. E-mail Address: N/A

5. Home Phone:

(555)555-5555

6. Pager Number/Cell: N/A

(555)555-5555

7. Home Address:

City: State: CA

8. Age:

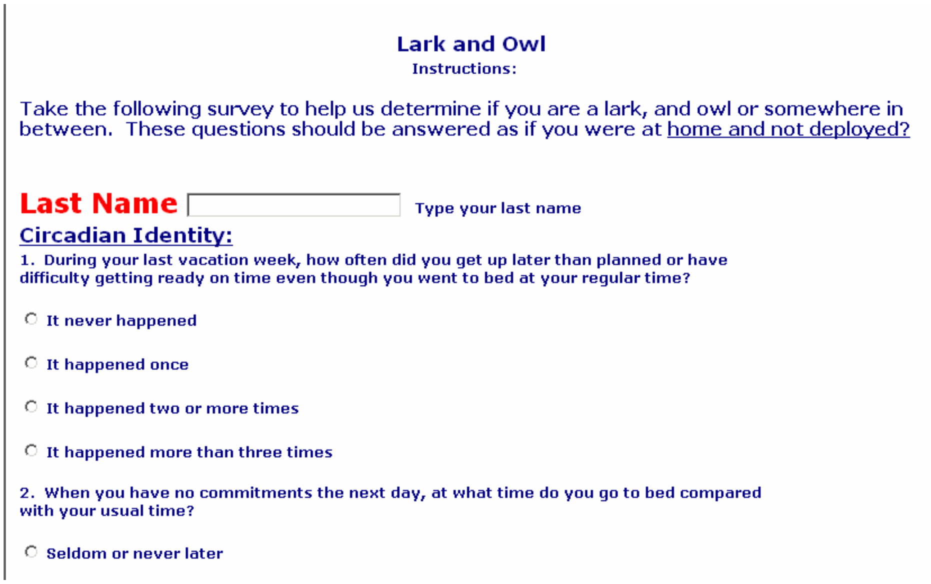
9. Gender: Male Female

10. Height: 4 feet 0 inches (round to the nearest inch)

11. Weight: lbs

12. Do you wake up to an alarm clock? Yes No

Figure 17. Demographic Survey Template Form



Lark and Owl
Instructions:

Take the following survey to help us determine if you are a lark, and owl or somewhere in between. These questions should be answered as if you were at home and not deployed?

Last Name Type your last name

Circadian Identity:

1. During your last vacation week, how often did you get up later than planned or have difficulty getting ready on time even though you went to bed at your regular time?

- It never happened
- It happened once
- It happened two or more times
- It happened more than three times

2. When you have no commitments the next day, at what time do you go to bed compared with your usual time?

- Seldom or never later

Figure 18. Lark and Owl Template Form

As indicated earlier, if the web is not accessible to the participants, copies of these forms (shown in Appendix D) are included in the MS Access Study Repository Template Database.

b. Log Database Design

After careful investigation of existing PDA logging programs, no logging software for PDAs was available to record the types of events SMEs had articulated for the daily event log. Though the log was easy to design using MS Access, there was no way to export this desktop version to an application available for the PDAs. The NPS IT staff does not currently have a site license for any PDA database development software. Programming applications for PDA use was beyond the scope of our expertise. After evaluating several packages available on the commercial market as well as freeware, we chose HanDBase 3.0 for our PDA database development. This program provides the capability to create and modify databases from both a desktop and PDA platform. HanDBase offered enough functionality and technical support to meet study requirements. We created a simple log database template using HanDBase software which is fairly easy to modify. Because no site licensing was available for HanDBase 3.0, a license is required for every PDA.

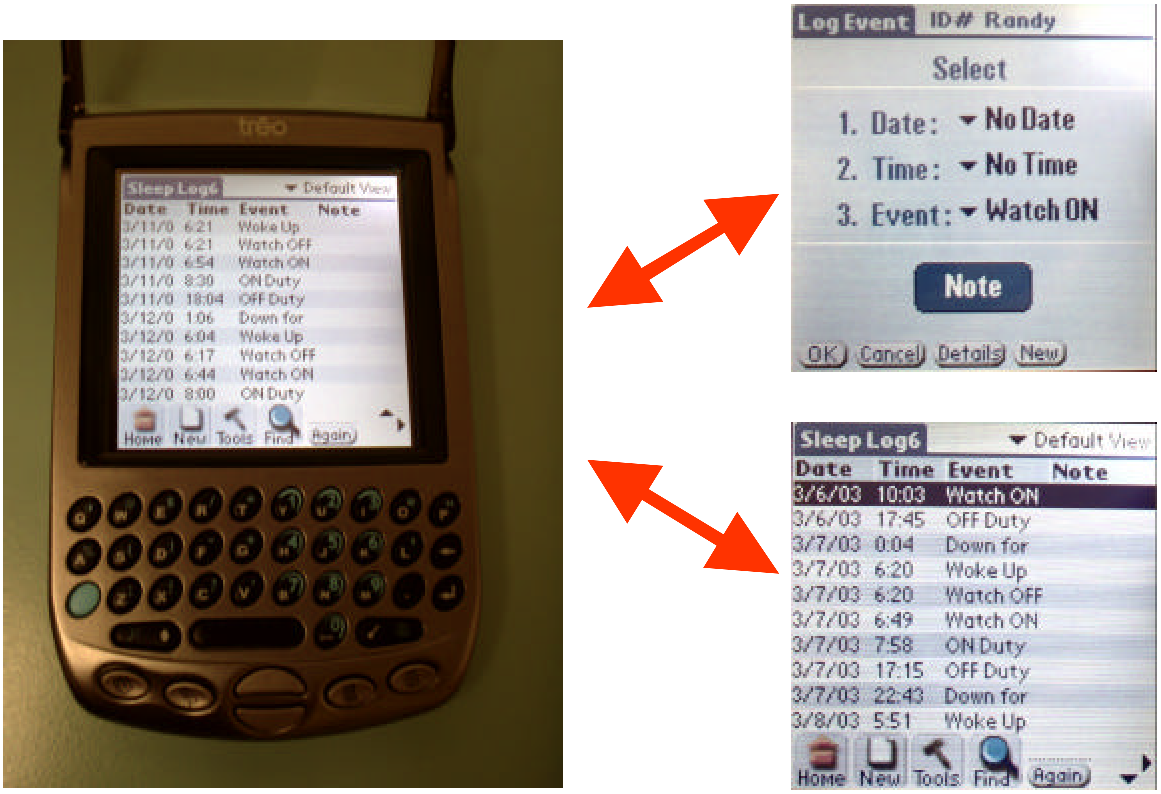


Figure 19. PDA Event Log Template

Loaded on each PDA, the log database enables a participant to record an event, the date and time of the event and a short note if clarification is required. The events we included in the template are generic and can easily be modified to include particular events the researchers would like to capture for a given study. A screen capture from the PDA of the Event Log Template with sample data is shown in Figure 19. The recorded data are stored on a file in the PDA and can be downloaded to a PC using the HotSync function of the PDA. The HanDBase software includes a desktop version allowing the data from each PDA to be easily consolidated and exported to a MS Excel spreadsheet.

c. Collecting ARES (ANAM^{TM} Readiness Evaluation System) Data

A collection means for performance data is available on the PDA using ARES software shown in Figure 20. Researchers generally require participants to complete a designated ARES battery of tests (e.g., reaction time, running memory, and sleepiness scale) at least three times a day. Data are recorded for each test and are stored into a PDA database file. When the PDA performs a HotSync function with the laptop, these

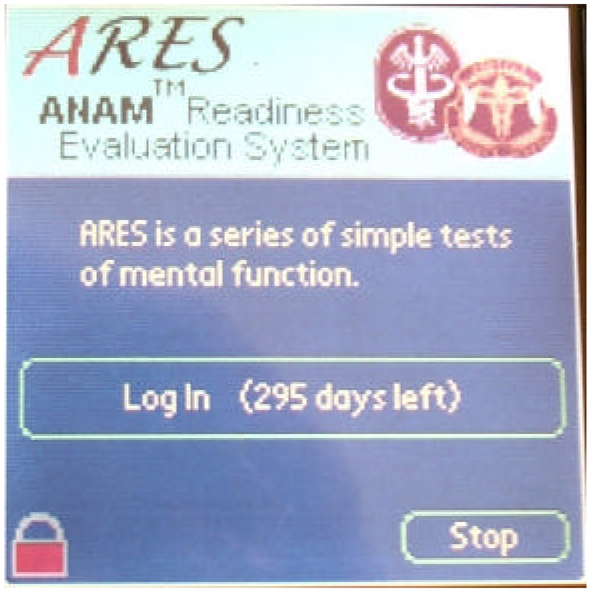


Figure 20. ARES Software for the PDA

d. Research Team Input Forms

Data are saved to a database file which is able to be read only by the Data Manager software.

Figure 21 shows the raw data in Data Manager software. From Data Manager, the researcher can use the copy function to copy the data to a MS Excel spreadsheet for analysis (shown in Figure 22).

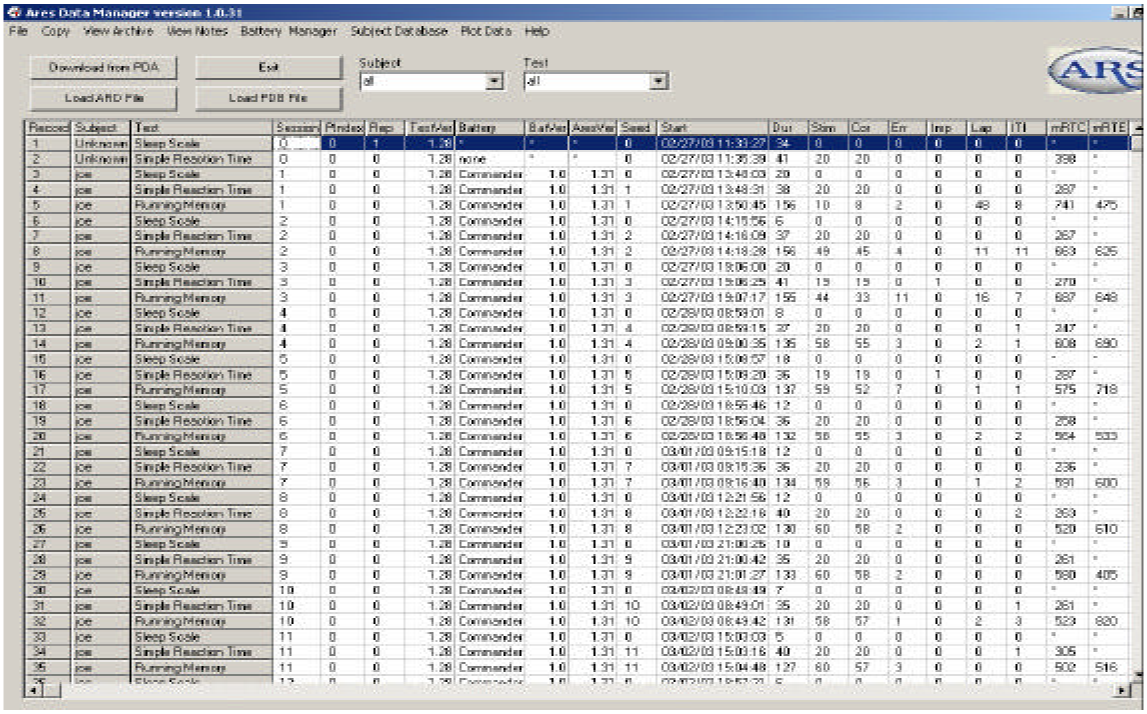


Figure 21. Raw ARES Data in Data Manager Software

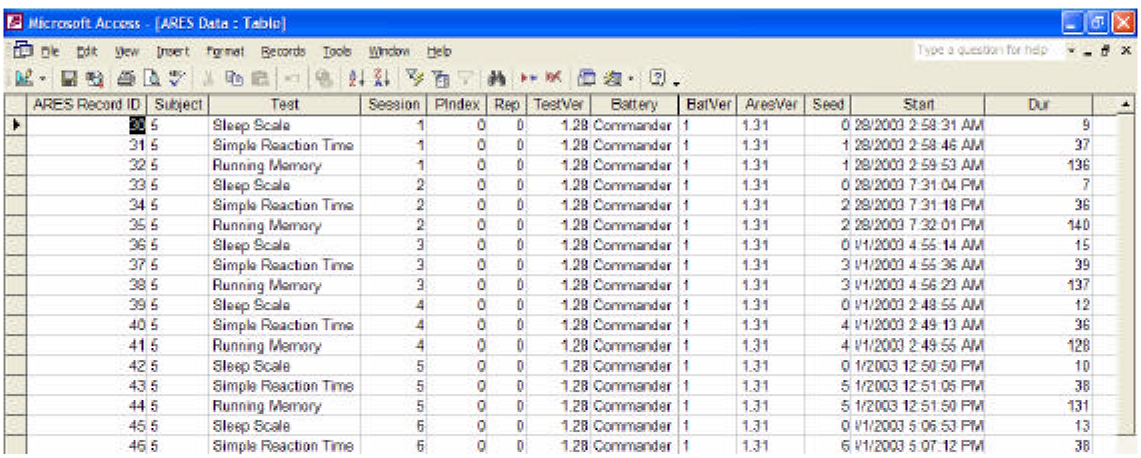


Figure 22. Raw ARES Data Copied to MS Access Database

Other data maintained by research teams will also be collected electronically. Information on the research team and study parameters will be recorded by the researchers using automated input forms shown in Figure 23 and Figure 24 respectively. Additionally, researchers will maintain and update equipment statuses, assign equipment to participants and record status of collection of data and equipment from participants at the end of a study using simple input forms. All input forms available in the Study Repository Template Database are also shown in Appendix D. The use of these electronic forms increases the efficiency of the research team's ability to conduct the study and minimizes human errors associated with tracking by pen and paper.

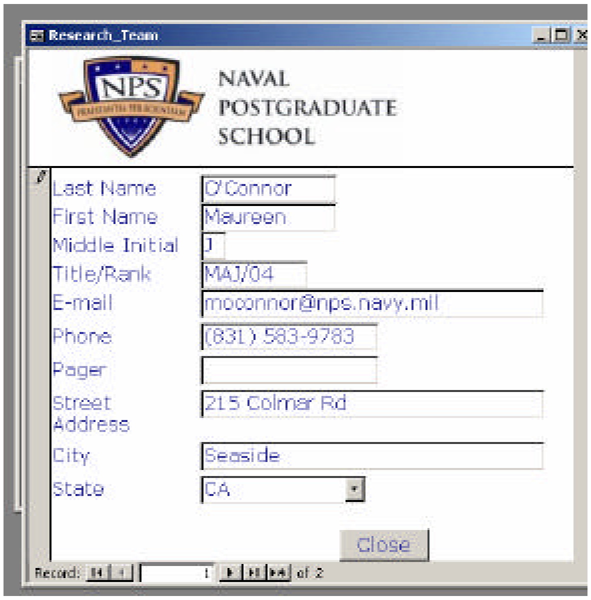


Figure 23. Input Research Team Information Form

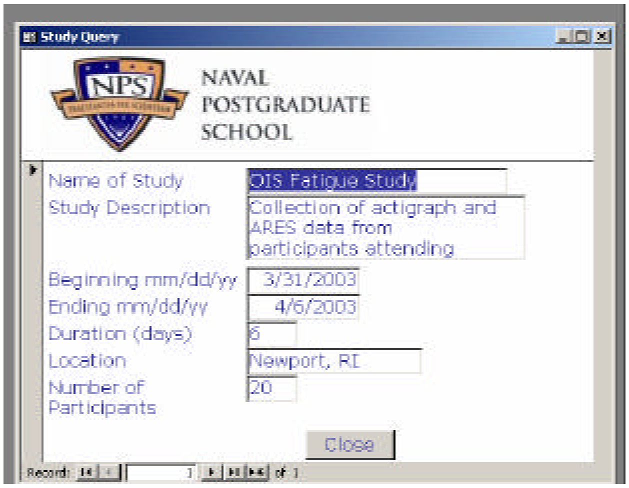


Figure 24. Input Study Information Form

2. Database Design

We chose Microsoft Access 2002 as the software to create our Study Repository Template Database because it provided adequate support for small relational database development. It is fairly easy to use and it is supported by NPS IT staff. There were no additional licensing requirements to use it and there is a fairly extensive MS Access knowledge base at NPS to assist research teams with database modifications. We examined the feasibility of using the latest version of Extensible Markup Language (XML) developed and supported by the World Wide Web Consortium (W3C) to create the database to avoid proprietary issues and created a prototype database using XML Spy software. While there are many benefits to using XML, the current W3C version of XML does not easily support relational databases and the complexity involved in maintaining referential integrity for our database proved too complex. According to the W3C discussion groups, future versions of XML will provide more capabilities to develop relational databases. Microsoft has created a version of XML (MSXML) which supports relational database development; however, MSXML is not W3C compliant and is clearly proprietary. Additionally, MSXML is not exclusively a database development tool. Creating databases using MSXML requires extensive knowledge of the XML language as well as a thorough understanding of databases. Because of its maturity as a product, MS Access 2002 proved to be a more robust solution for us to use. If future W3C versions of XML support relational databases adequately, the Study Repository Template database we have created can be exported to a XML format for modification and maintained as an XML database for suture use.

Transforming entities to relations, we recognized the attributes identifying each entity and made these the primary keys of the relations. When any of these primary keys were required as attribute of other relations, we depicted them as foreign keys. Figure 25 depicts the relationships created using MS Access 2002. The highlighted text in each relation indicates the primary key(s).

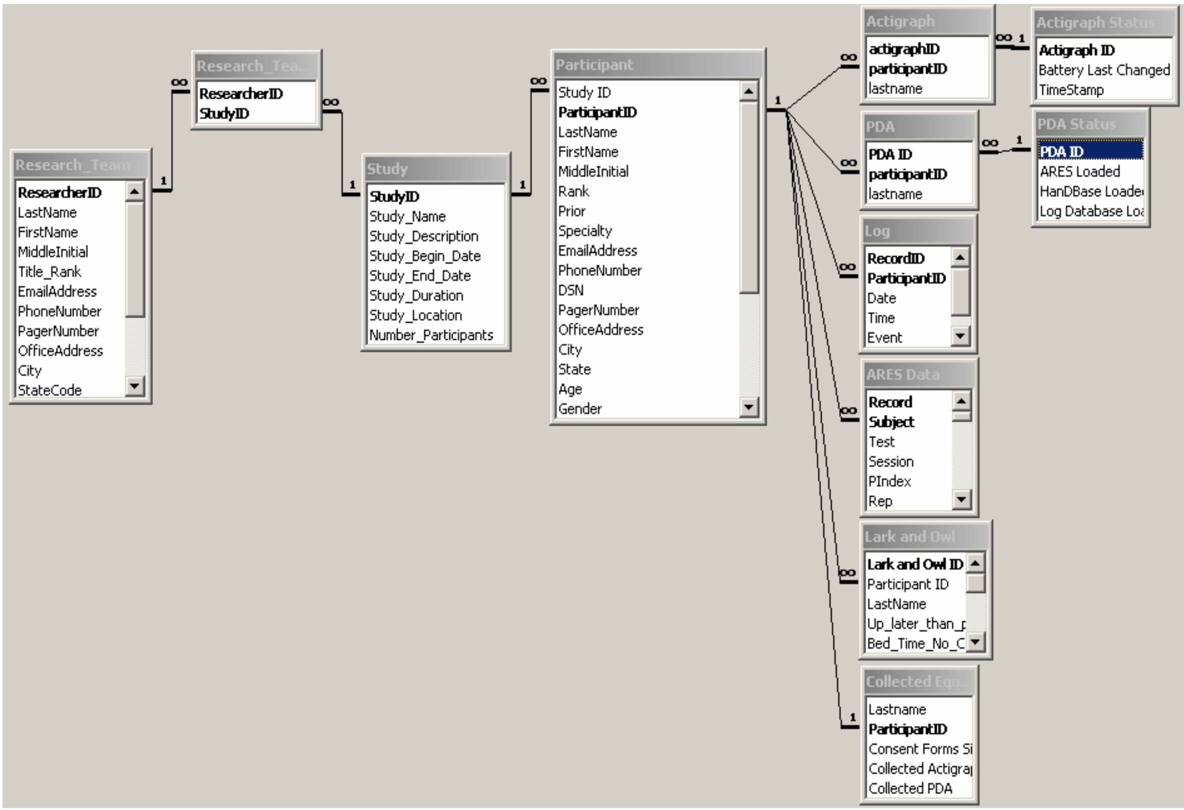


Figure 25. Study Repository Template Relationships

3. Application Design

The Study Repository Template Database was designed to provide research teams with a robust database to which minor modifications can be made to tailor it for a given study. In designing our database application, no mechanisms for limiting control were necessary because the research team will be the administrators of their modified databases. In this template design, input forms and reports were created to allow the research team to input data efficiently and retrieve data in useful formats for data analysis. A Main Menu Form was created to allow researchers to easily navigate their way through these useful forms and reports.

E. IMPLEMENTATION PHASE

1. Creating the Database

We published the template web surveys, created the event log on the PDA, loaded ARES on the PDA and created the research team input forms according to the design. After these data collection methods were refined, we were able to finalize the Study

Repository Template Database design and create it using Microsoft Access 2002. A listing generated by the Access program of the database tables, their properties, and relationships can be found in Appendix C. In Appendix D, graphical representations of all forms and reports available from the Main Menu Form of the Study Repository Template Database are also available. This database resides on the HSIL web server along with the web survey forms. The Event Log and the ARES program are loaded on PDAs in the HSIL and the accompanying software to both of these programs is loaded on the desktops in the HSIL as well as the laptop that accompanies the research team to the location of the studies conducted.

2. Storing Data to the Database

At the start of a study, the research team can enter data to the RESEARCH TEAM and STUDY tables using the forms from the Main Menu Form shown in Figure 26. These forms are also displayed in Appendix D. Researchers can also update the status of the Actigraphs and the PDAs in the ACTIGRAPH STATUS and PDA STATUS tables respectively, using input forms available from the same Main Menu Form.

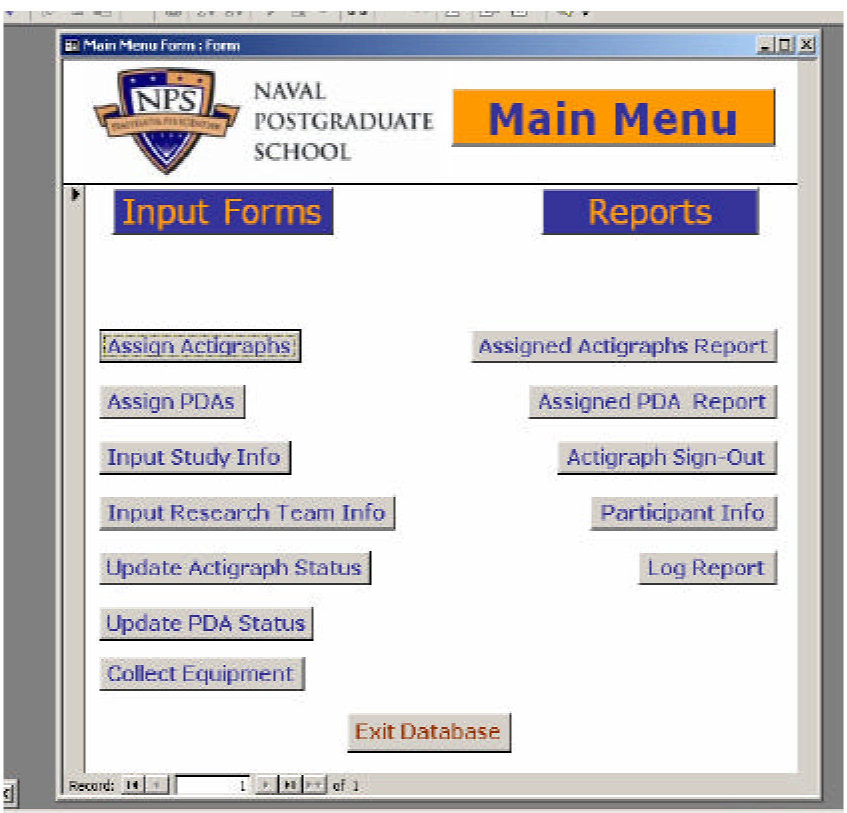


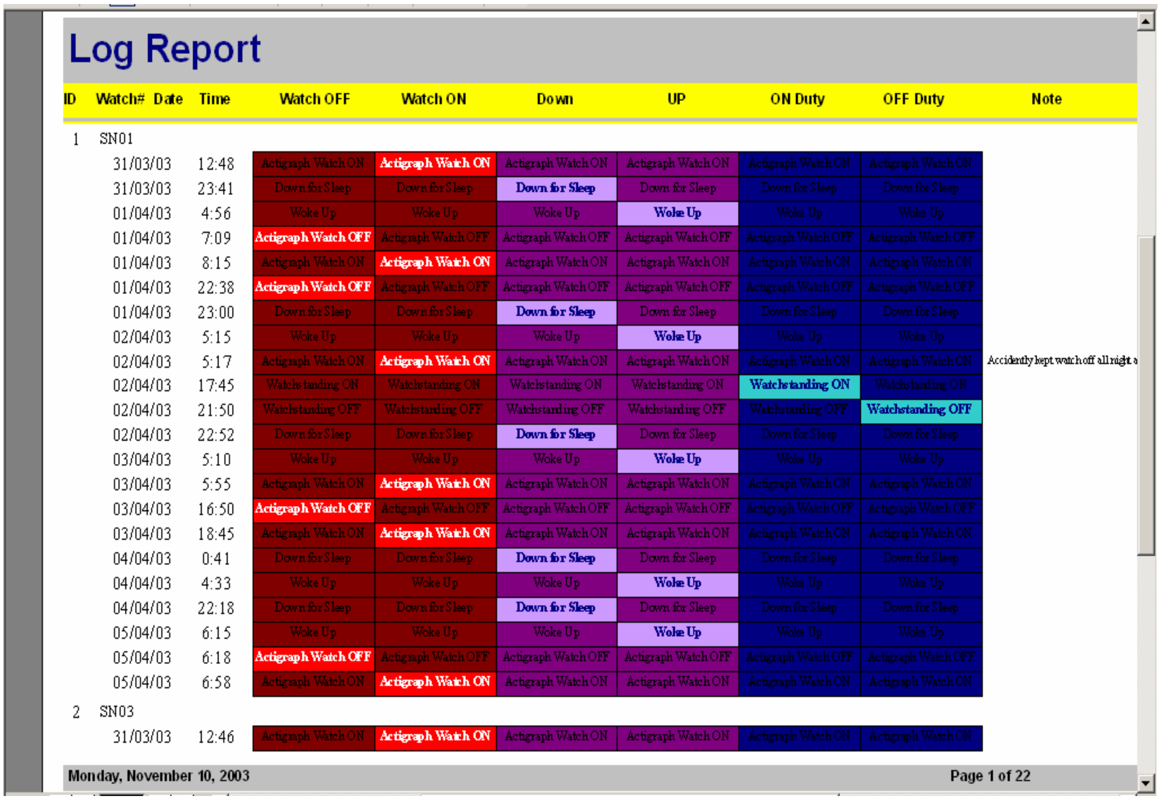
Figure 26. Main Menu Form

After the participants have been identified and have completed the online surveys, the Study Repository Template Database automatically updates the PARTICIPANT and LARK AND OWL tables when the repository study database is opened with the data that has been entered by participants via the web and saved to the Demographic and the Lark and Owl databases. If web access is not available to the participants, the research team can allow the participants to complete the input forms created with MS Access available from the Main Menu Form. If the participants have no access to computers, these input forms can even be printed if necessary and the researcher can add the data to the database using the completed printed forms and the database input form to ease the transfer of data from paper to the database. The researchers can update the ACTIGRAPH and PDA tables using the Assign Actigraph and Assign PDA Forms respectively, shown in APPENDIX D. After the research team downloads the ARES and LOG data from PDAs to MS Excel spreadsheets, the datasheets are copied to the respective tables. Finally, as the research team collects equipment, they can use the Collect Equipment Form to update the COLLECT EQUIPMENT AND DATA table.

Various reports are available to the research team to use during or after the study and are also accessible from the Main Menu Form. Examples of all of these reports available are shown in Appendix D. These were designed to assist the researchers with assigning and keeping track of equipment used in the study as well as to print the final event log. This Log Report, shown in Figure 27, includes conditional formatting which allows the research team to easily code the actigraphy data and correlate the participants' effectiveness with their daily activities using FAST and ARES analysis tools.

3. Application Implementation

Though the research team will modify the design template to suit the individual study requirements, the Main Menu Form allows the researcher to easily navigate through the database updating information and generating valuable reports as needed. This Main Menu Form can also be modified to accommodate the database changes made for a particular study or to add more useful reports required for the research being conducted.



Log Report

ID	Watch#	Date	Time	Watch OFF	Watch ON	Down	UP	ON Duty	OFF Duty	Note
1	SN01									
		31/03/03	12:48	Actigraph Watch ON	**Actigraph Watch ON**	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	
		31/03/03	23:41	Down for Sleep	Down for Sleep	**Down for Sleep**	Down for Sleep	Down for Sleep	Down for Sleep	
		01/04/03	4:56	Woke Up	Woke Up	Woke Up	**Woke Up**	Woke Up	Woke Up	
		01/04/03	7:09	**Actigraph Watch OFF**	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	
		01/04/03	8:15	Actigraph Watch ON	**Actigraph Watch ON**	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	
		01/04/03	22:38	**Actigraph Watch OFF**	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	
		01/04/03	23:00	Down for Sleep	Down for Sleep	**Down for Sleep**	Down for Sleep	Down for Sleep	Down for Sleep	
		02/04/03	5:15	Woke Up	Woke Up	Woke Up	**Woke Up**	Woke Up	Woke Up	
		02/04/03	5:17	Actigraph Watch ON	**Actigraph Watch ON**	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Accidently kept watch off all night a
		02/04/03	17:45	Watchstanding ON	Watchstanding ON	Watchstanding ON	Watchstanding ON	**Watchstanding ON**	Watchstanding ON	
		02/04/03	21:50	Watchstanding OFF	Watchstanding OFF	Watchstanding OFF	Watchstanding OFF	Watchstanding OFF	**Watchstanding OFF**	
		02/04/03	22:52	Down for Sleep	Down for Sleep	**Down for Sleep**	Down for Sleep	Down for Sleep	Down for Sleep	
		03/04/03	5:10	Woke Up	Woke Up	Woke Up	**Woke Up**	Woke Up	Woke Up	
		03/04/03	5:55	Actigraph Watch ON	**Actigraph Watch ON**	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	
		03/04/03	16:50	**Actigraph Watch OFF**	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	
		03/04/03	18:45	Actigraph Watch ON	**Actigraph Watch ON**	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	
		04/04/03	0:41	Down for Sleep	Down for Sleep	**Down for Sleep**	Down for Sleep	Down for Sleep	Down for Sleep	
		04/04/03	4:33	Woke Up	Woke Up	Woke Up	**Woke Up**	Woke Up	Woke Up	
		04/04/03	22:18	Down for Sleep	Down for Sleep	**Down for Sleep**	Down for Sleep	Down for Sleep	Down for Sleep	
		05/04/03	6:15	Woke Up	Woke Up	Woke Up	**Woke Up**	Woke Up	Woke Up	
		05/04/03	6:18	**Actigraph Watch OFF**	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	
		05/04/03	6:58	Actigraph Watch ON	**Actigraph Watch ON**	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	
2	SN03									
		31/03/03	12:46	Actigraph Watch ON	**Actigraph Watch ON**	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	

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Figure 27. Log Event Report

When this template design was created, we assumed participants would have access to the web to provide survey information. If this is not possible, researchers can recreate these surveys using MS Access forms. When the system is used in this capacity, it is important for the research team to incorporated adequate control mechanisms to allow participants to enter and verify data while preventing them from accessing restricted data. The Help feature in MS Access outlines these control features in a "how-to" format that is easy for the researchers to follow. For the forms created using MS Access in the database template, constraints were used to reduce the potential for data entry errors for the research team. Many forms include drop down lists and check boxes to prevent ambiguity or misrepresented data. An example of this is the Assign Actigraphs Form shown in Figure 28. The drop down list for the Actigraph Number is taken from the query based on the ACTIGRAPH STATUS Table. This not only ensures researchers label the numbers with the same format but also eliminates the error of assigning an Actigraph that has not been added to the ACTIGRAPH STATUS Table. Similarly, the dropdown list for the Participant's Last Name is available from a query based on the PARTICIPANT table allowing the researcher to only assign Actigraphs to identified participants. Also, once the name is selected, the Participant ID field is automatically filled with the Participant ID associated with the selected name.

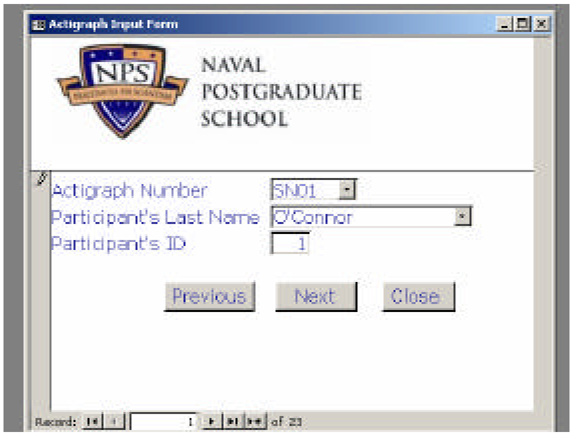


Figure 28. Assign Actigraph Input Form

F. EVALUATING THE REENGINEERED PROCESS

The entire application including the web Demographic and the Lark and Owl Surveys, the PDA Event Log, the ARES Program for the PDA, the Study Repository Template Database with research input forms along with the Actigraphs was packaged and tested. A group of volunteer students at NPS were modeled as a group of study participants. As the simulated research team, we asked them to take the web surveys, wear the Actigraph watches, take the ARES battery of tests on a set schedule and log their daily events with the PDA for a period of a week. We recorded study and research team information, updated the equipment statuses, and assigned equipment to the participants after they had completed the web surveys. At the conclusion of the week, we collected the equipment and downloaded the data from the Actigraphs and PDAs. We copied the ARES and Log Data to the database and conducted exit interviews with the participants. Making no significant modifications, we were satisfied with the prototype of the "TO-BE" process.

V. REENGINEERED PROCESS

A. OVERVIEW

The newly created IT tools described in Chapter IV were incorporated into the reengineered "AS-IS" process. In this chapter, the new "TO-BE" process is outlined. Using the seven step KVA process, the "TO-BE" process Return on Knowledge (ROK) was calculated at the process and sub-process levels using very conservative estimates to provide the means for comparison of the "AS-IS" to the "TO-BE" process. A report of the evaluation of this KVA comparative analysis is also provided. At the conclusion of this chapter, a discussion of the potential for a dramatic increase to ROK through implementation of a radical redesign to the process is offered. This impact of this radical redesign for the Department of the Navy and possibly other services in the Department of Defense is worthy of consideration.

B. "TO-BE" PROCESS MODEL

As we conducted the test in the laboratory using the volunteer students as participants, we carefully reengineered the "AS-IS" process. Incorporating the newly designed data collection techniques and the database template, we were able to model the "TO-BE" fatigue study process. Applying the KVA methodology, we determined the core and sub-processes for the "TO-BE" process. Though the titles of these remain the same as in the "AS-IS" process, many of the subordinate activities and tasks changed. A complete set of diagrams of these sub-processes, activities and tasks is provided with KVA calculations in APPENDIX A. The following paragraphs highlight the significant changes made and the impact they have for the efficiency and accuracy of the data collection and analysis conducted by research teams from the HSIL at NPS.

1. Phase 1: Collect Data Sub-Process

The major reengineering effort happened in this phase. Figure 29 depicts the Collect Data Sub-Process of the "AS-IS" process as the baseline for comparison and Figure 30 shows the Redesigned Collect Data Sub-Process of the "TO-BE" process. The Prepare Data for Collection Activity now includes modifying the Study Repository Template Database, modifying the Demographic Survey on the HSIL webpage, appending the Lark and Owl Survey to the webpage, and modifying the PDA Event Log.

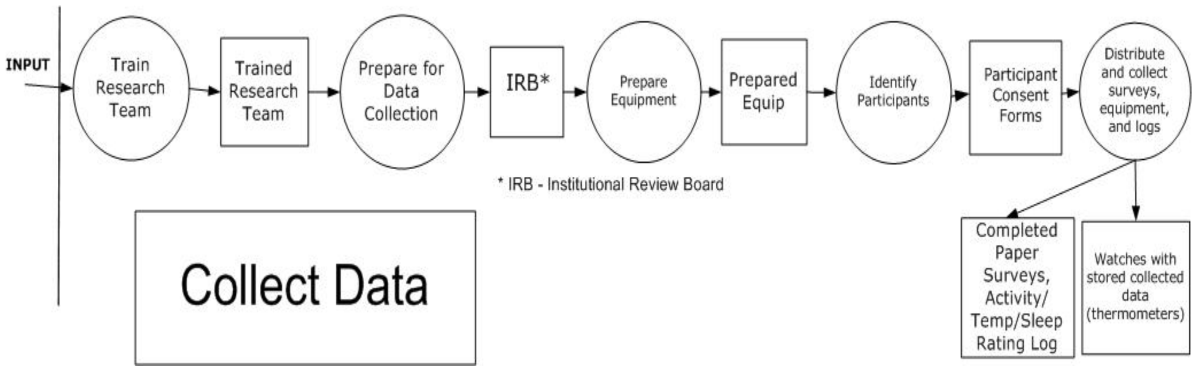
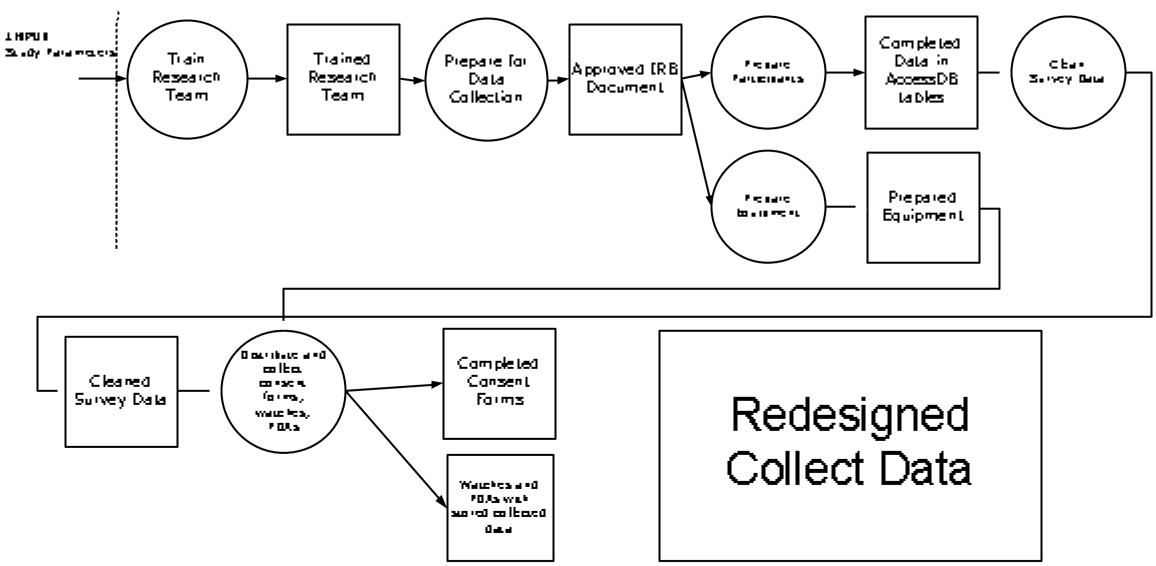


Figure 29. AS-IS Collect Data Sub-Process



http://www.nps.navy.mil/humanfactors. The web surveys, their corresponding databases and the Study Repository database are all stored on the server. These administrative tasks take considerably less time than those under the corresponding "AS-IS" activity because the researchers modify existing templates rather than create them on their own. Additionally, by completing these tasks at this point in the process, the research team is prepared to collect survey data via the HSIL webpage once participants have been identified by the sponsoring organization of the study. This participant survey data are also checked for completeness and screened for potential errors or issues. This pre-screening of participant data allows researchers the ability to prevent the 20% loss of data generally experienced using the "AS-IS" process.

Once the participants are recorded in the database, the equipment is prepared. The Actigraph watches are initialized and assigned by serial number to the participants using the Assign Actigraph Form. The PDAs are similarly assigned by name (e.g., HSIL1, HSIL2 etc.) to participants using the Assign PDA Form. The HanDBase software and the Study Event Log database file and form file are loaded onto the PDA. Additionally, the ARES software is loaded onto the PDAs and each participant is registered by participant ID and the particular battery of tests is selected. Consent forms are printed and all equipment and forms are bundled for issue under the Prepare Equipment Activity. This activity can now be completed prior to the research team ever arriving at the study location. A tremendous burden is lifted from the researchers by doing so. Now they can come to the study location and focus on collecting accurate actigraphy, ARES performance data and log data instead of worrying about the logistics of identifying participants and tracking the assignment and issue of equipment to them. During the collection process, researchers can check participant data for completeness by routinely downloading data from the Actigraphs and the PDAs. This ensures that equipment is working properly, participants are taking their ARES tests, and that they are adequately logging their daily behavior. At the end of this sub-process, the research team will have a record of the study parameters and the research team information as well as "clean" participant and Lark and Owl data loaded in their database. They will have PDAs and Actigraphs with data stored on them and signed participant consent forms. Compared with the "AS-IS" sub-process, the research team will have collected more accurate data and will have already completed all of the survey data preparation for analysis by the end of this phase in the "TO-BE" process.

2. Phase 2: Prepare Data for Analysis Sub-Process

Comparing the "AS-IS" Prepare Data for Analysis Sub-Process shown in Figure 31 to the "TO-BE" Sub-Process shown in Figure 32, the Input Data to Excel Spreadsheets Activity and the Clean Data Activity are eliminated. Because the Demographic and Lark and Owl survey data have been collected and verified for completeness in the Collect Data Sub-Process, the only data requiring preparation for analysis in the “TO-BE” Prepare Data for Analysis Sub-Process would be the Event Log data, the Actigraph data, and the newly added ARES data.

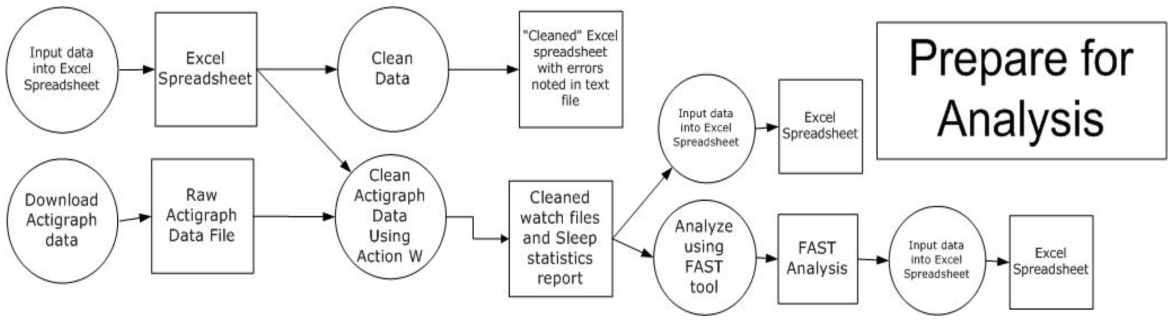
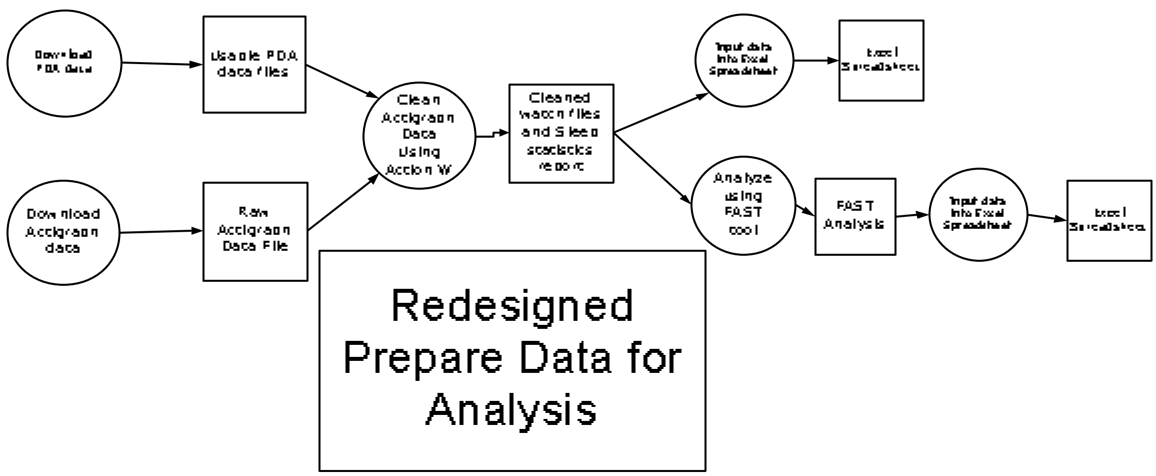


Figure 31. AS-IS Prepare Data for Analysis Sub-Process



loads the ARES Data (.PDB file) and copies the data to the ARES Data table in the Study Repository database. The research team can use the Data Manager software to conduct analysis and the data in the MS Access table can be exported easily to other data analysis software. The Event Log Data are viewed with the HanDBase Desktop software and copied to the Log table in the Study Repository database. Without further manipulation, the Log Report is generated by clicking the "Log Report" command button on the Main Menu Form in the database. The conditionally formatted Log Report highlights the "ON/OFF" state of an event, for example Actigraph Watch ON and Actigraph Watch OFF. The report is generated in chronological order by participant. On the web server, a Study Repository folder

At the heart of fatigue studies are the actigraphy data. The scoring algorithm used in the Actigraph software determines whether a sleep epoch is classified as either sleep or wake. Based on a participant's log and a researcher's subjective expertise, the Actigraph data must be "cleaned." If the software coded low activity levels as sleep when the participant was really awake, the participant may be wrongfully thought to have had more sleep and thus potential higher performance effectiveness than he actually had. To accurately portray a participant's activity, the sleep/wake log is essential. Figure 33 shows a participant's Actigraph data over a period of a few days. The sleep algorithm in the Action W Software scored the low activity levels in the circled area as sleep. The intermittent activity shown during this time could lead a researcher to concur with the Actigraph software and assume the participant was asleep. In this case, however, the accompanying log report, shown in Figure 34, clearly indicates that during that time, the participant had removed his Actigraph watch but was not asleep. By recoding the sleep data as wake data, the researcher is able to more accurately represent the behavior of that participant. Because of the format of the Log Report, it is easy to see the changes of state a participant goes through chronologically. The highlighted events allow the research team to easily compare the recorded actigraphy with the log report to trim the data. This ease of this comparison not only saves researchers many hours of trimming data but it also yields a more accurate assessment of the participant's activity than the "AS-IS" process does using paper logs. Because the Actigraph data files can only be read by Action W and FAST software in particular data formats (.AMI and .EBE respectively), it is not useful to translate these files into MS Access formats. Instead, the Actigraph and FAST files (both raw and "cleaned") are saved to the Study Repository folder on the server.

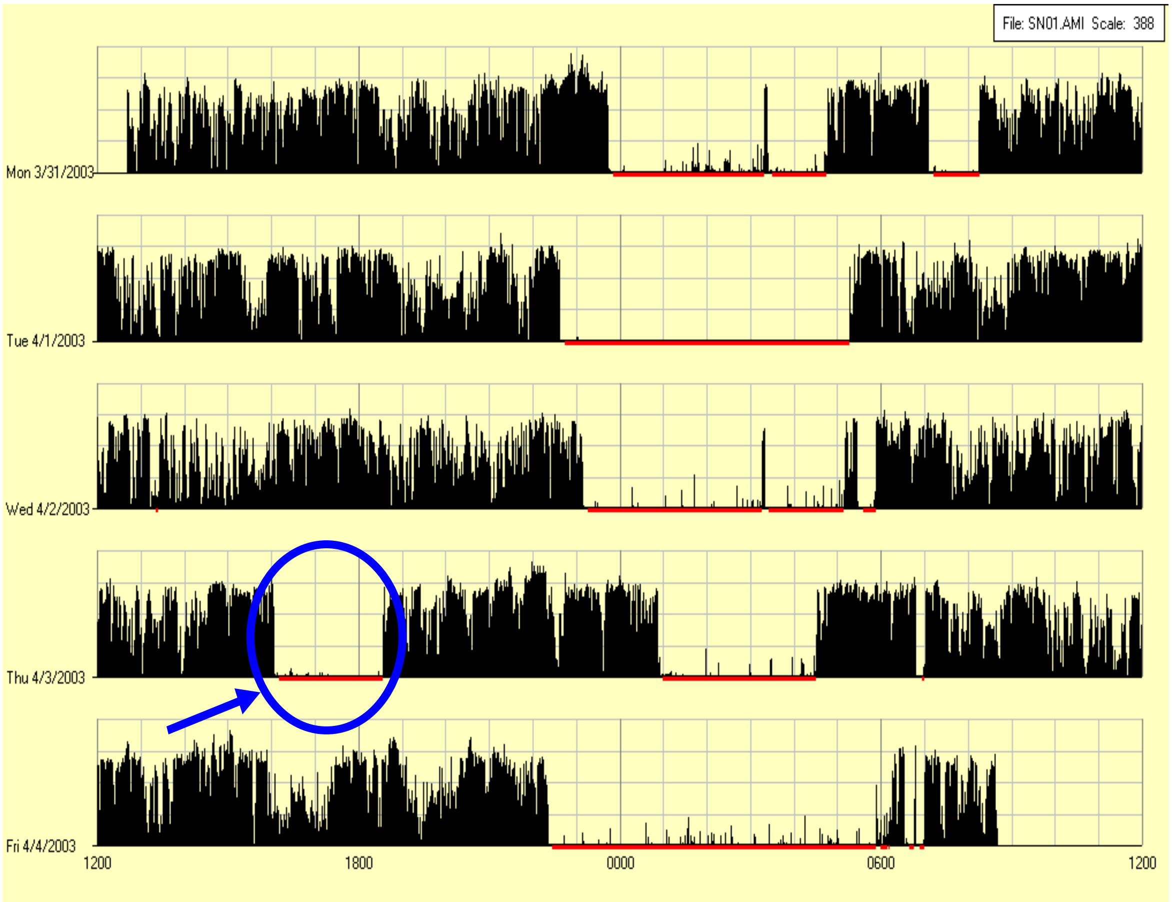


Figure 33. Raw Actigraph Data of Participant 01

Log Report

ID	Watch#	Date	Time	Watch OFF	Watch ON	Down	UP	ON Duty	OFF Duty	Note
1	SN01									
		31/03/03	12:48	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	
		31/03/03	23:41	Down for Sleep	Down for Sleep	Down for Sleep	Down for Sleep	Down for Sleep	Down for Sleep	
		01/04/03	4:56	Woke Up	Woke Up	Woke Up	Woke Up	Woke Up	Woke Up	
		01/04/03	7:09	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	
		01/04/03	8:15	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	
		01/04/03	22:38	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	
		01/04/03	23:00	Down for Sleep	Down for Sleep	Down for Sleep	Down for Sleep	Down for Sleep	Down for Sleep	
		02/04/03	5:15	Woke Up	Woke Up	Woke Up	Woke Up	Woke Up	Woke Up	
		02/04/03	5:17	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Accidently kept watch off all night after
		02/04/03	17:45	Watchstanding ON	Watchstanding ON	Watchstanding ON	Watchstanding ON	Watchstanding ON	Watchstanding ON	
		02/04/03	21:50	Watchstanding OFF	Watchstanding OFF	Watchstanding OFF	Watchstanding OFF	Watchstanding OFF	Watchstanding OFF	
		02/04/03	22:52	Down for Sleep	Down for Sleep	Down for Sleep	Down for Sleep	Down for Sleep	Down for Sleep	
		03/04/03	5:10	Woke Up	Woke Up	Woke Up	Woke Up	Woke Up	Woke Up	
		03/04/03	5:55	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	
		03/04/03	16:05	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	
		03/04/03	18:35	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	
		04/04/03	0:41	Down for Sleep	Down for Sleep	Down for Sleep	Down for Sleep	Down for Sleep	Down for Sleep	
		04/04/03	4:33	Woke Up	Woke Up	Woke Up	Woke Up	Woke Up	Woke Up	
		04/04/03	22:18	Down for Sleep	Down for Sleep	Down for Sleep	Down for Sleep	Down for Sleep	Down for Sleep	
		05/04/03	6:15	Woke Up	Woke Up	Woke Up	Woke Up	Woke Up	Woke Up	
		05/04/03	6:18	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	Actigraph Watch OFF	
		05/04/03	6:58	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	Actigraph Watch ON	

Figure 34. Log Report Data for Participant 01

The most significant change to the second phase of the process is that the researchers do not have to transpose data from paper to electronic format. Not only does this save the time of entering the data into spreadsheets but more significantly, it also eliminates the countless hours spent comparing the spreadsheets with the original paper entries to verify the data accuracy. Secondly, another tremendous benefit of this redesigned sub-process is the amount of time saved in "cleaning" the Actigraph data using the Log Report generated from the raw Event Log data. Next, the standardized format included with the data collection and storage templates decreases the amount of time researchers spend formatting and storing their data. Finally, the addition of the ARES data provides a valuable performance measure for the research team while requiring minimal time to download the data using the HotSync function and to copy it to the MS Access database. In total, this "TO-BE" Redesigned Prepare Data for Analysis Sub-Process will take less than half the cycle time to complete than the "AS-IS" Prepare Data for Analysis Sub-Process while providing the research team with more accurate data to analyze.

3. Phase 3: Analyze and Publish Sub-Process

The data analysis piece of the third phase of the "TO-BE" fatigue study process is very similar to that of the "AS-IS" process. The thesis output of the sub-process is the same. The major difference is the inclusion of the Study Repository database as the means of data storage available for reuse in the "TO-BE" process. Figure 35 shows the "AS-IS" Analyze and Publish Sub-Process. The "TO-BE" Redesigned Analyze Data, Publish Analysis and Store Study Data Sub-Process depicted in Figure 36 shows the addition of Clean MS Access Database to the Write Thesis Activity resulting in the new Study Repository folder including the database and complimentary data files as an output product of the sub-process.

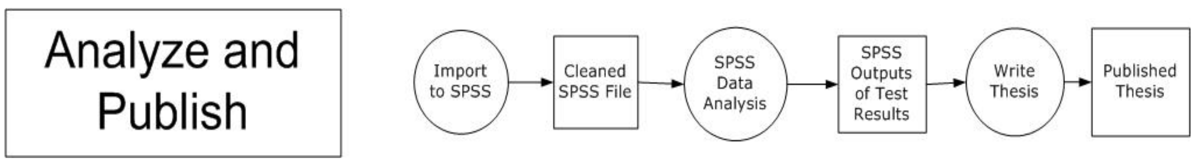
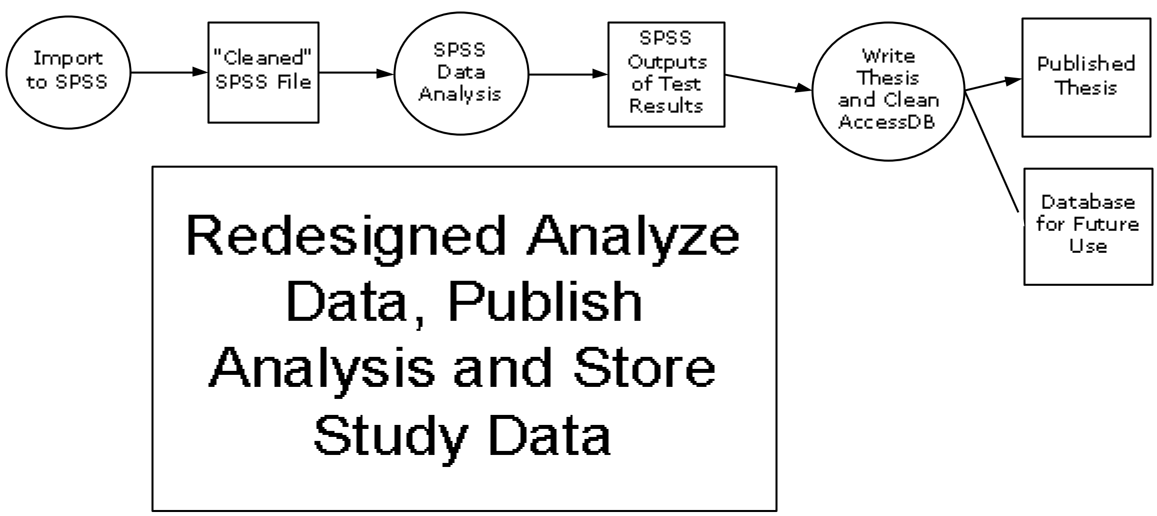


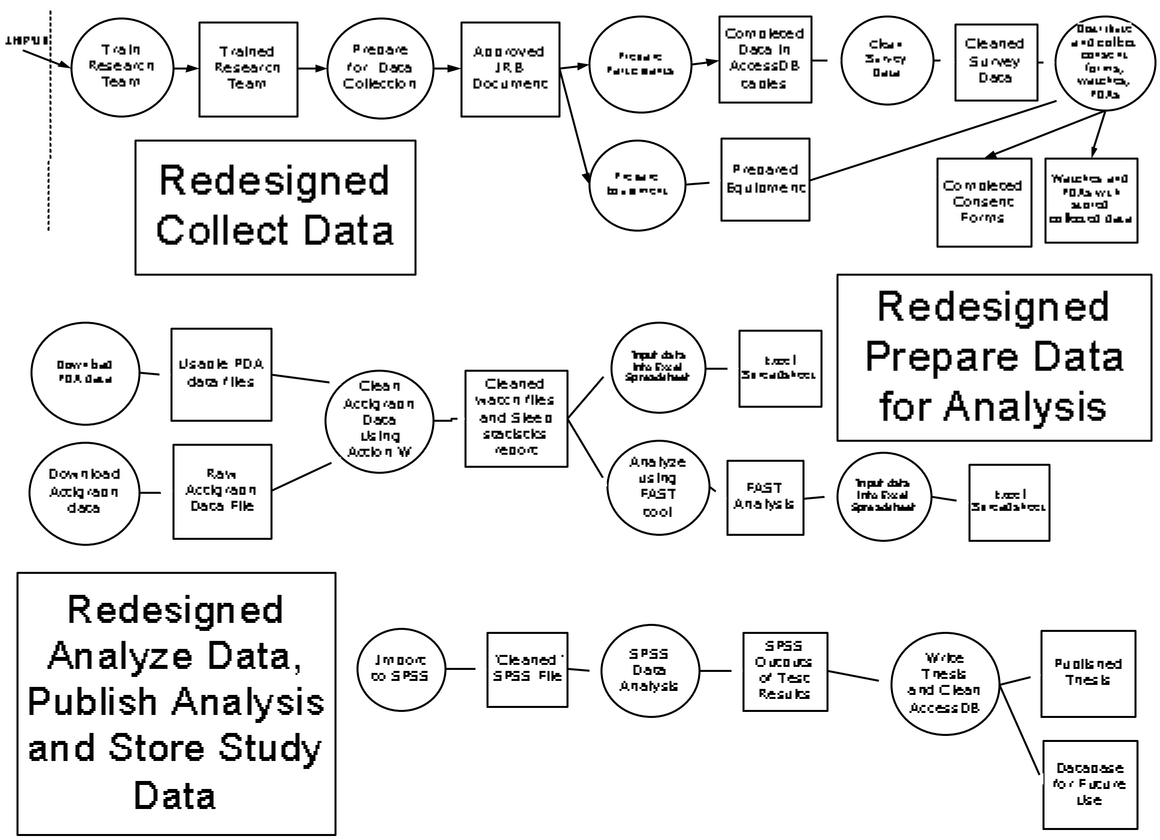
Figure 35. AS-IS Analyze and Publish Sub-Process



analysis and does not have to waste time designing a storage method. The Study Repository database allows them the option to add tables for analyzed data results and to add or modify reports for inclusion in the published documentation of the study. MS Access empowers the researcher with flexibility to efficiently utilize the collected data. Additionally, the standard format allows those interested in the fatigue research of the HSIL at NPS to more easily access and interpret the collected, analyzed and stored data of the operational fatigue studies.

C. RETURN ON KNOWLEDGE FOR "TO-BE" PROCESS USING KVA ANALYSIS

To calculate a ROK (Return on Knowledge) of the newly redesigned sub-processes in order to compare it with the current process, we used the seven step KVA methodology. A summary of the reengineered "TO-BE" core process and sub-processes identified in STEP 1 are shown in Figure 37.



We kept the same units of hours to calculate learning time as we did in STEP 2 for the "AS-IS" analysis. In STEP 3, the learning time for each task was calculated. The sampling time period of one year remained the same as was used for the "AS-IS" for STEP 4. In STEP 5, we calculated the weighted learning time for each sub-process. For the tasks that remained the same, we carried their learning times from the "AS-IS" process. For the newly incorporated tasks, we used the expertise of the SMEs and our own to determine the learning time. Because of the dramatic reduction in cycle time for the entire process, we conservatively estimated that the number of studies conducted each year could easily double in number. Additionally, the less obtrusive means of collection will most likely allow for an increase in the average number of participants per study. As a conservative measure, we kept 25 as the average number of participants per study for our calculations. However, due to the streamlined efficiency of collecting and cleaning survey data from participants prior to arriving on site, we maintain that the research team will be able to collect useable data on all 25 participants. When calculating the weighted learning time of a task, we multiplied the learning time of a task (included associated IT learning time if applicable) with the number of times the task was executed in a given sample period. Since the average number of participants is 25 and the number of studies conducted per year increased to two, the weighted learning time for a task such as initializing Actigraphs would be the total learning time multiplied by 50. Cumulative weighted learning times were calculated for the process and sub-process level. Similarly in STEP 6, the cost to execute each task was calculated as well as the cumulative costs of each sub-process. To determine the ROK according to STEP 7, the ratio of weighted learning time divided by cost was calculated. A comprehensive table of calculations by task is included in Appendix A.

A comparative summary of the calculated ROK between the "AS-IS" process and the "TO-BE" process is shown in Table 2. Though the estimations were conservative, the ROK of the "TO-BE" process more than doubles that of the "AS-IS" process. The efficient data collection means of the "TO-BE" process clearly enables the research teams to analyze more data in a timely and efficient manner producing more accurate results.

The bottoms-up approach we used of evaluating KVA from the task level to the entire process captured with granularity the increased ROK.

Sub Processes	Weighted Learning Time (Hrs)	Total Cost ($)	As-Is ROK	To-Be ROK
Collect Data	289	3300	9%	
	1810	4246		43%
Prepare for Analysis	1158	8278	14%	
	3075	9185		33%
Analyze and Publish	1161	10192	11%	
	6885	32082		21%
TOTAL	2608	21770	12%	
	11770	45513		26%

Table 2. Comparison of "AS-IS" ROK to "TO-BE" ROK

Additional benefits of the reengineered process that have yet to be realized. Perhaps the most notable of these is the addition of the data repository for all the HSIL studies conducted at NPS which will enable researchers to conduct meta-analysis across many studies. Additionally, the standardization of the "TO-BE" process and the ability to save methods used for each study conducted may allow an even greater number of studies to be conducted per year the pool of resources available to thesis student fatigue researchers becomes richer with every completed study.

D. IMPACT OF A DRAMATIC PROCESS REENGINEERING EFFORT

The goal of the fatigue research conducted today and in the near-term future at the HSIL at NPS is to evaluate participant data and provide feedback to commanders on the effects of fatigue as it impacts human performance effectiveness. Migrating from the "AS-IS" process to the "TO-BE" process will certainly allow researchers to achieve this goal more efficiently and with greater volume potentially allowing the ability to generate more representative data. However, what if the goal was expanded to provide commanders with near real time assessments of fatigue and performance effectiveness to allow them to make smarter decisions?

By further dramatic process reengineering, this goal could be realized. Instead of focusing research on determining past performance effectiveness, the HSIL at NPS could provide commanders with more predictive tools to assess current conditions and risks associated with fatigue and provide the commanders with strategies to mitigate given circumstances to increase this effectiveness for a particular mission. By packaging the data collection process into "How-To" type fatigue assessment kits issued to each ship, sailors and other service members could be assessed in their operational environments. Data collected aboard the ship by trained members of the crew could be sent electronically to the team of researchers at the HSIL where they would conduct their analysis and provide feedback to the commanders. A rough estimate of the ROK for the Dramatic Redesign was calculated and is shown in Appendix A. A summary of the ROK results compared with the "AS-IS" and "TO-BE" processes are shown in Table 3.

Sub Processes	Weighted Learning Time	Total Cost	As-Is ROK	To-Be ROK	Dramatic ROK
Collect Data	289	3300	9%		
	1810	4246		43%	
	395760	370425			107%
Prepare for Analysis	1158	8278	14%		
	3075	9185		33%	
	1204500	2062500			58%
Analyze and Publish	1161	10192	11%		
	6885	32082		21%	
	254250	1122413			23%
TOTAL	2608	21770	12%		
	11770	45513		26%	
	1854510	3555338			52%

Table 3. Comparison of "Dramatic" ROK to "AS-IS" and "TO-BE" ROK

A repository of successfully mitigated obstacles could be retained and shared as a "Lessons Learned" type of tool for leaders to use. The staff of researchers at the HSIL would certainly have to increase and could not be limited to thesis students but the incredible return provided to the entire Navy could positively impact the success of future missions and reduce number of accidents and other incidents caused by human error due to fatigue.

VI. NAVAL OFFICER INDOCTRINATION SCHOOL STUDY

A. OVERVIEW

The reengineered process was validated using participants from the Naval Officer Indoctrination School (OIS) in Newport, RI (Figure 38). To accomplish the validation, we designed a study to emulate the NPS Fatigue Study Process. Because the objective of our study was to evaluate the "TO-BE" process, we did not seek to answer any particular fatigue related questions with this study. Instead, using our newly designed templates, we wanted to determine if data could be collected, manipulated and stored more easily and with less data corruption.

Figure 38. Naval Officer Indoctrination School

We selected the Newport location primarily because the daily routine of OIS students is highly regimented. This regimentation allowed us to more easily monitor the data collection process and to address issues as they arose. Additionally, the staff and faculty at OIS understood our intent and graciously allowed us to evaluate our process at their facility. Although the reengineering process was the focus of our study, we did collect human fatigue and performance data on students and faculty at OIS. These actigraphy and ARES performance data were collected on 20 participants from 31 March

2003 to 5 April 2003. We conducted only preliminary data analysis to evaluate the changes we had incorporated into the "TO-BE" process, however, we did not conduct an in depth analysis of the data. Since the preliminary analysis revealed interesting observations with regard to human fatigue and performance, we have made our OIS Study data available for further analysis by fatigue researchers on the HSIL web server and it is anticipated that NPS students will use the data for further analyses.

Broken into phases, this chapter provides a summary of the OIS Study followed by lessons learned. Using the templates created in the reengineering effort, we tailored them for this specific study. We collected survey data using the web surveys, actigraphy using the Actigraph watches, logging data using the event logger on the PDA and performance data using the ARES software, also on the PDA. By conducting an actual field study, we were able to experience firsthand the pressures facing a research team in a field environment. Through our own experience and observations, we were then able to modify the templates we had designed in order to provide maximum functionality to future research teams. The results of this OIS study serve as a validation of the reengineered efforts reflected in the "TO-BE" process.

B. PHASE 1: COLLECT DATA SUB-PROCESS

In the weeks preceding the OIS study, we completed tasks similar to those required by fatigue research students under the sub-process activities: Train Research Team and Prepare for Data Collection. Using the "TO-BE" process additions, we revised the Study Repository Template database on the HSIL web server (http://www.nps.navy.mil/HumanFactors) and saved the newly revised OIS Study Repository database to the server. We entered the research team information and the study information using the input forms in the database. Once the decisions had been finalized on what data we would collect, we were able to modify the Institutional Review Board (IRB) proposal documentation template and submit the proposal for approval. We saved a copy of the IRB proposal documentation to the server.

After the IRB proposal was approved, we modified the survey and log templates to fit the OIS Study. The Demographic questionnaire and Lark and Owl surveys were posted to the website and PARTICIPANT and LARK AND OWL tables in the OIS Study Repository database were set to be updated as data was entered into the web surveys.

The use of append table queries allowed the OIS Study database to automatically check for new updates on the web server and append them upon opening of the database. The PDA Event Log Template was modified to allow participants to log when they took the Actigraph watch off and put it back on, when they went down for sleep and when they awoke, and when they stood watch. The newly modified log was called Sleep_Log_OIS.

Under Prepare Participant Activity, coordination was made with the OIS cadre to identify 20 participants for the study and to ask them to complete the web surveys. As they completed these, we could monitor their submitted survey data using the OIS Study Repository database. If any survey data field was incomplete, we were able to coordinate through the cadre to rectify the problem. As a result, we were able to collect all 20 of the participants' survey data with minimal missing values. Participants completed online documentation the week prior to the study start date. Had we been actual fatigue researchers, the Lark and Owl data could also have been evaluated allowing the opportunity to connect morningness/eveningness information with each participant. As participants were added, the database automatically assigned participant ID numbers to each person. Using these numbers, we were able to conduct the tasks under the Prepare Equipment Activity. We initialized the Actigraph watches and assigned each to a participant using the database input form. We also prepared the ARES and logging PDA software for download to the PDAs. Because we were going to use the PDAs that had been issued to the participants by OIS, we could not prepare the PDAs until we arrived on site.

Arriving a day before the actual Actigraph data collection was scheduled to begin, we were able to meet with participants to collect their PDAs and coordinate for redistribution of the devices. We also were able to clarify any missing entries made to their survey data which resulted in "already-cleaned" Demographic questionnaire and Lark and Owl data. We synchronized each participant's PDA with the standard Palm Desktop software that accompanies the PDA software. Since these PDAs were already in use by the participants, we could not rename them to conform to our naming convention for PDAs of HSIL1, HSIL2, etc. which we had used in our template design. This would have required us to delete everything on their PDAs. As each PDA "user" name was added to our synchronizing software, we recorded this name into the PDA table of our

OIS Repository and added the corresponding Participant ID for each PDA. Once the PDAs were connected with Participant IDs, we loaded the ARES and logging software to each PDA. We also loaded the newly modified OIS Sleep Log file, Sleep_Log_OIS.PDB, and the OIS Sleep Log Input Form file, Sleep_Log_OIS_HDF.PDB, to each PDA. In preparing each log, we selected the appropriate participant ID number for each PDA using the HanDBase 3.0 desktop software and these two files. Although this participant's "ID#" field displays on the PDA log view (Figure 39), the user cannot modify it.

Figure 39. PDA Quick Link Buttons

When the data are collected, this participant ID number allows the researcher to identify whose data was downloaded. Similarly, using the registration menus on the ARES software on the PDA itself, we registered each participant using the corresponding participant ID and we set each to use the Commander Battery of tests. This battery includes a sleepiness scale, a reaction time test and a running memory test. Because the participants were in a classroom environment, we chose not to set their PDA alarms to alert them to take their ARES tests though this technique proved to be helpful when we tested it at the HSIL. To assist participants, we did set the Memo Pad and To Do List buttons on the bottom of the PDA (Figure 39) to open the Log and ARES respectively for quick and easy data entry.

The following morning, we distributed the Actigraph watches, PDAs and informed consent forms and instructed the participants on to the use of the PDA software. Once the signed consent forms were collected, we began the 5-day data collection phase. During the course of data collection, we periodically verified data integrity by collecting the Actigraphs and PDAs and downloading the data. One Actigraph device failed during the study and a replacement watch was given to the participant. Throughout this process, the participant continued to log his activities.

Once the data collection period had ended, all Actigraphs and PDAs were collected. We synchronized the PDAs using the Palm Desktop software to collect the log and ARES data, deleted the ARES and logging software from the PDAs and then returned the PDAs to the participants. As we did this, we used the Collected Data and Equipment Form on the OIS Study Repository to track our progress.

At the end of the Prepare for and Collect Data Sub-Process, we had PDA data files and Actigraph data files stored on the computer for each participant, signed consent forms and the Actigraph watches with stored data. Additionally, the OIS Study Repository database included completed and cleaned STUDY, RESEARCH TEAM, PARTICIPANT, and LARK AND OWL tables and cross-references for PDAs and Actigraphs to the participants in the PDA and ACTIGRAPH tables. Formatted reports were also available from the OIS Study Repository to assist in the data analysis phase.

C. PHASE 2: PREPARE DATA FOR ANALYSIS SUB-PROCESS

We began this phase with the Download PDA Data Activity. As a result of the PDA HotSync, each participant's sleep log data included in the file Sleep_Log_OIS.PDB from the PDA was copied to the C:\Palm\[PDA_name]\Backup location on the laptop hard drive. From the HanDBase desktop software, we opened each of these files and appended each participant to one consolidated Sleep_Log_OIS.PDB file. We then exported that data file to MS Excel and copied it directly to the LOG table in the repository database. The pre-formatted Log Report in the database generated a consolidated, color coded log of each of the participant's activities. Similarly, we prepared the ARES data by loading the ARSubjDB.PDB file of each participant stored in the C:\Palm\[PDA_name]\Backup location on the laptop. Unlike HanDBase however, the Data Manager software does not have an append function. Therefore, we copied each participant's ARES data directly from Data Manager to the ARES DATA table in the OIS Study Repository database using the cut and paste function. We saved all of the log and ARES original .PDB files to the HSIL web server in the OIS Study Repository folder.

Using the Actigraph interface device, we downloaded the actigraphy data using Act Millennium software and saved each file with the serial number as the filename as a .DAT file and .AMI file (e.g., SN01.DAT and SN01.AMI). Because the Actigraph data files can only be opened from inside the Act Millennium and Action W software, there was no reasonable way to store this data into the database. Therefore, we stored both of these files on the web server. The ACTIGRAPH table in the database provides the key to identifying the corresponding Actigraph serial number(s) for each of the participants.

Actigraphy data were trimmed and marked according to the Log Report of the participants' activity using Action W software. The data files were saved as .AMI files and .EBE files with an "A" added to the filename (e.g., SN01A.AMI and SN01A.EBE) to allow both the raw and trimmed data to be easily identified. All of these files were stored on the web server. Using the summary statistics of Action W for each participant, the average number of hours of sleep per night calculated for the participants was recorded. This average of six hours was used to precondition the preceding three days of the template schedule using the FAST software. Each .EBE file was then loaded into the template FAST schedule with the preconditioned preceding three days. Each participant's FAST data was saved as a FAST schedule using the .FAS file extension (e.g., SN01.FAS). These FAST schedules were also added to the OIS Study Repository folder on the web server. For the participant whose watch had failed and had been issued a second watch, we were unable to combine the data from both watches into one Action W data file; both sets of data were cleaned and stored into two respective files based on the log. Because the participant kept an accurate log including the time between the first watch failing and the second watch beginning to record data, it was possible to manually input the sleep/wake from the first watch's failing through the end of the study period into FAST using the Action W file from the second watch and the log. This provided an accurate measure of the participant's predicted effectiveness and made it possible for keep this participant's data in the study. After all Actigraph data were "cleaned" and predicted cognitive effectiveness was modeled in FAST for each participant, screen captures of the trimmed Action W files and the FAST schedules for each participant were also imported into a PowerPoint presentation and saved on the server.

By the end of the Prepare Data for Analysis Sub-Process, all participants' raw and "cleaned" data files were well-organized on the web server for easy access as was a summary presentation file including the actigraphy and FAST performance effectiveness for each participant. The OIS Study Repository database included updated LOG and ARES tables and the data from all 20 of the participants was prepared for analysis. As projected by our KVA calculations, we expected the cycle time for this sub-process to decrease by half. Because of the standardized templates and storage methods as well as the efficiently coded log data easing the burden of "cleaning" actigraphy, the actual cycle time for this sub-process for this study was less than one forth of the corresponding sub-process cycle time in the "AS-IS" model.

D. PHASE 3: ANALYZE AND PUBLISH SUB-PROCESS

Because the data analysis portion of this sub-process did not change from the "AS-IS" process to the "TO-BE" process, we did not conduct an in-depth analysis of the sleep data. We did, however, request the assistance of research analysts to verify that the data could be analyzed efficiently in their stored formats. One of the researchers that assisted us in this evaluation was LT John Nguyen who had conducted the USS JOHN C. STENNIS Study. In his assessment, the prepared data were ready for analysis. As a result of the standardized formatting and efficient activity logs, he estimated that he could have saved months of time had he had this "TO-BE" process available to him prior to conducting his study. A second researcher looked at the ARES data and determined that from its stored format in the repository database, it could have easily been evaluated to determine possible correlations between performance and fatigue. There were some participants that did not complete the battery of tests the recommended three times per day. Because we were more interested in whether the data could be collected and downloaded efficiently, we did not adequately emphasize the importance of completing all required testing. In the future, researchers can download ARES data daily to ensure participant compliance for complete analysis.

Due to the ease of "cleaning" the Actigraph data, we were able provide the command at OIS some preliminary feedback on the participants' sleep/wake activity as well as performance effectiveness during the collection period. This was the first time such immediate feedback could be provided to a sponsoring organization. As a result of this feedback, the command requested the Actigraph data be collected for an additional period to evaluate the participants' performance during a battle drill exercise. Though no formal data analysis feedback was requested, the command was able to see the potential value provided by this fatigue study process to maximize student performance given their limited time in training. Another study may be warranted to answer specific questions for the OIS command in regard to fatigue management. Data collected from this study could be used as a baseline for comparison since it is available in the repository.

E. LESSONS LEARNED

As a result of this validation study, we were able to experience, firsthand, the challenges of conducting research on human in the field. In this context, we have made some valuable observations that impact future studies using our reengineered process. The following paragraphs summarize these observations in four major areas: 1) advantages of the PDA event logger, 2) PDA issues, 3) Actigraph issues, and 4) ARES issues.

1. Advantages of Event Logger

Trimming raw Actigraph data is time consuming using Action W software. To accurately represent a participant's data, researchers compare the data recorded in the sleep and activity log to the Actigraph data to verify whether the data are sleep or wake epochs and to record when an individual was down for sleep. When using a paper log, the researcher has to either transpose the log data to a spreadsheet or use the paper itself to compare with the Actigraph. In both methods, extracting the useful information from the log is tedious. In cases such as the USS JOHN C. STENNIS study, the inaccuracy of the paper logs resulted in the researcher having to eliminate the use of logs from his "cleaning" process only after many hours were spent trying to glean useful information from them. When they finally were eliminated, the researcher had to use a technique for trimming sleep data based on assumptions. Using this standard method for trimming data in the Action W software, researchers coded epochs where activity levels fell below 50 per epoch for 20 or more minutes as sleep periods. If the activity registered as a 0 for 10 minutes or more, the researcher assumed the participant had removed the Actigraph watch and coded the data as sleep or wake periods based on the duration and time of day. All other activity periods were classified as wake.

Using the PDA log, participants were much more likely to log their daily events because the method was easy for them to do so. When comparing log data with Actigraph data, the Log Report made "cleaning" the raw Actigraph data very simple. Figure 40 shows a screen capture of the method used during this "cleaning" process. The top window is the participant's raw Actigraph data in Action W software and the bottom window is his corresponding log data from the Log Report from the OIS Study Repository database. The researcher looks for the highlighted events and records them using the Action W tools. Using the participant number 52's data from the OIS study, we were able to "clean" his data in less than 5 minutes using this method. Using the standard trimming technique that the USS JOHN C. STENNIS researcher used to "clean" the data without a log on this same participant, it took approximately 15 minutes. These results were even a greater improvement than we had estimated in our KVA analysis (APPENDIX A). We tested these results on all of our participant data and found that on average, the standard trimming technique took more than three times as long to "clean" Actigraph data than when using the PDA log.

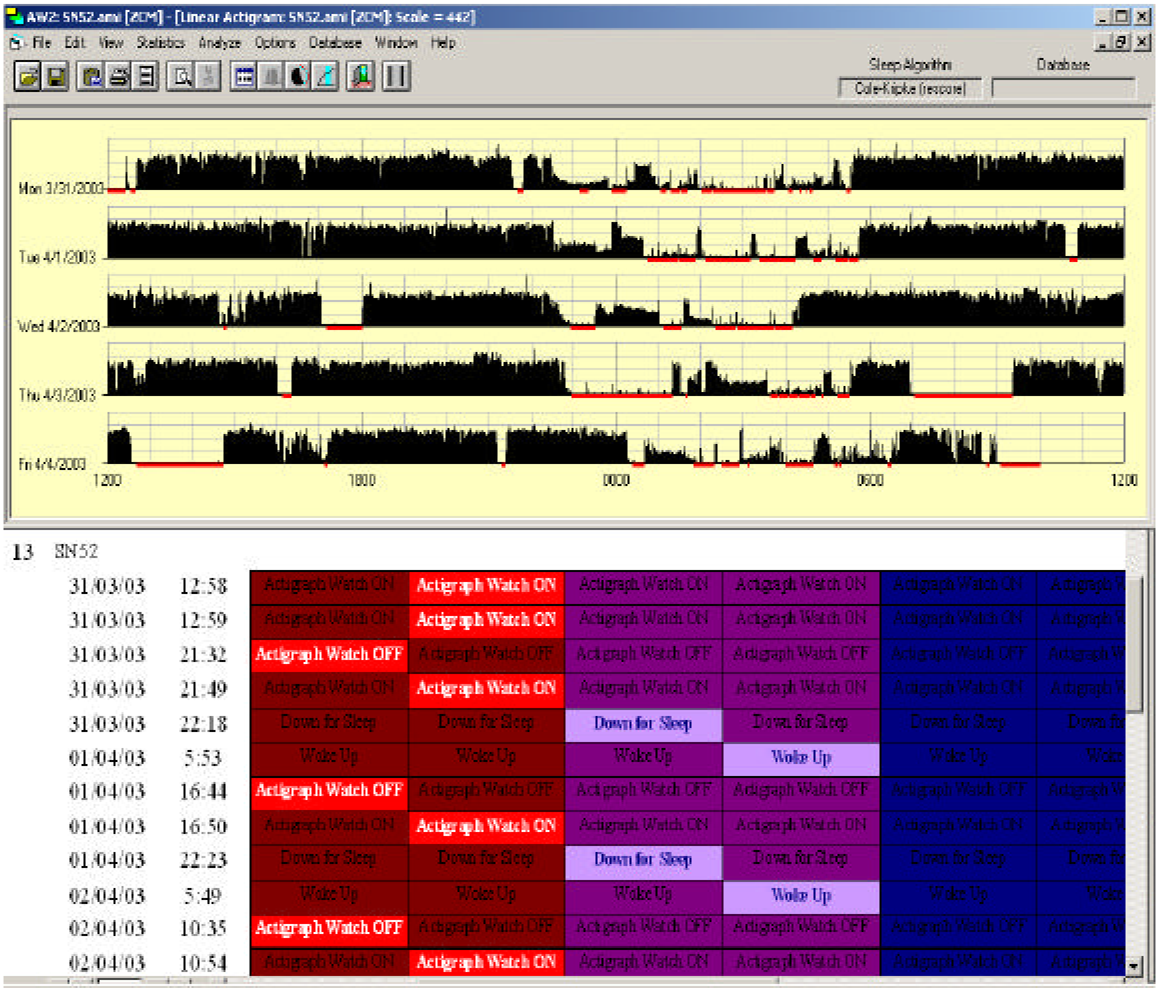


Figure 40. "Cleaning" Actigraph Data Using Action W and PDA Log Report

Not only is the PDA log method faster than the standard coding technique but it also appears significantly more accurate in some cases. Because of the convenience of the PDA log, participants are more likely to maintain their logs. Additionally, because the researchers can quickly compare log data with Actigraph data, they can routinely conduct data downloads to assess the quality of data collection and take corrective measures if needed. If there are unexplained data points, the researchers can clarify the issues with the participants while still there and while events are still fresh in their memory allowing the logs to more accurately reflect their behavior.

To emphasize the impact the log has on analyzing a participant's data, we compared the standard method of coding used in prior studies to the method of using the

PDA log. Using participant 52 from the OIS study again, Figure 41 shows this dataset trimmed with the standard coding technique. The red underlined epochs represent sleep periods; all other times are coded as wake. The aqua filled box periods represent the times a participant was down for sleep. Using this same participant in a comparative example, the Actigraph data were trimmed using the PDA based log (Figure 42). Because the activity levels did appear unusually high for sleep epochs, we asked participant 52 to verify the sleep log and verify our assessment of his actigraphy while still on site. He confirmed the events he had logged and assured us he had not awoken during his nights of sleep. Figure 43 shows a side by side comparison of the Actigraph data trimmed using both techniques. Without the log, many epochs were coded as wake as they did not fall below the threshold of 50 for at least 20 minute intervals. In the data "cleaned" using the standard coding technique, it appears as if the participant is getting much less sleep than he actually was.

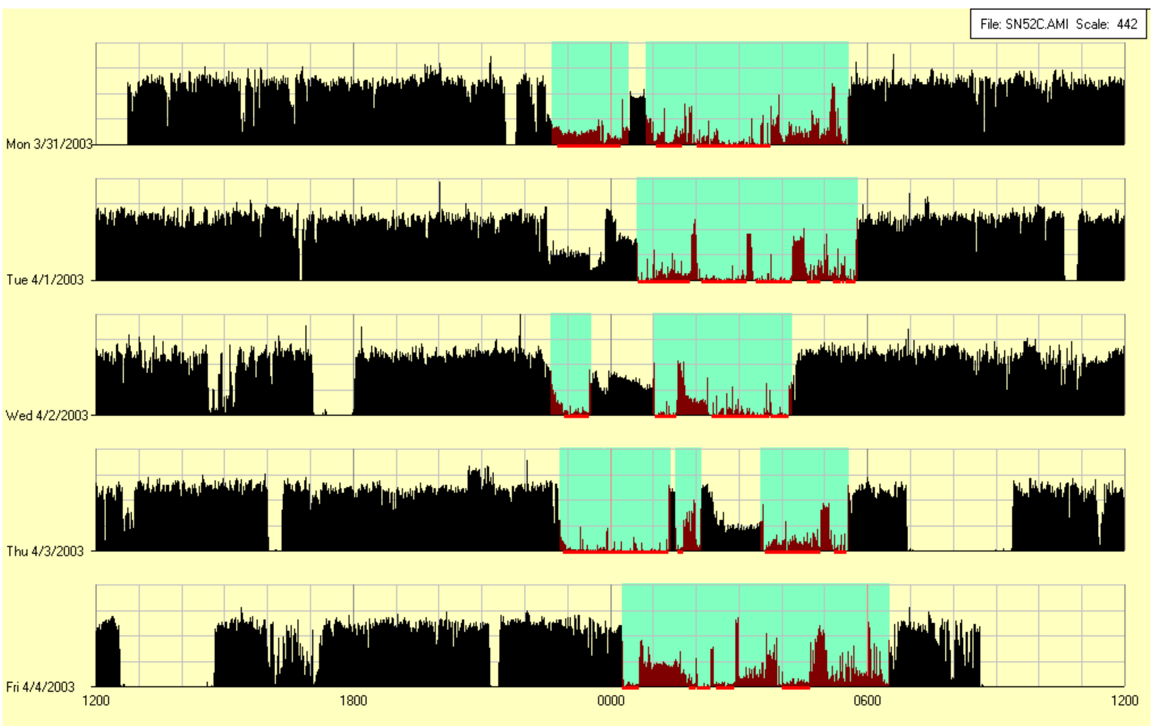


Figure 41. Actigraph Data Trimmed Using Standard Method

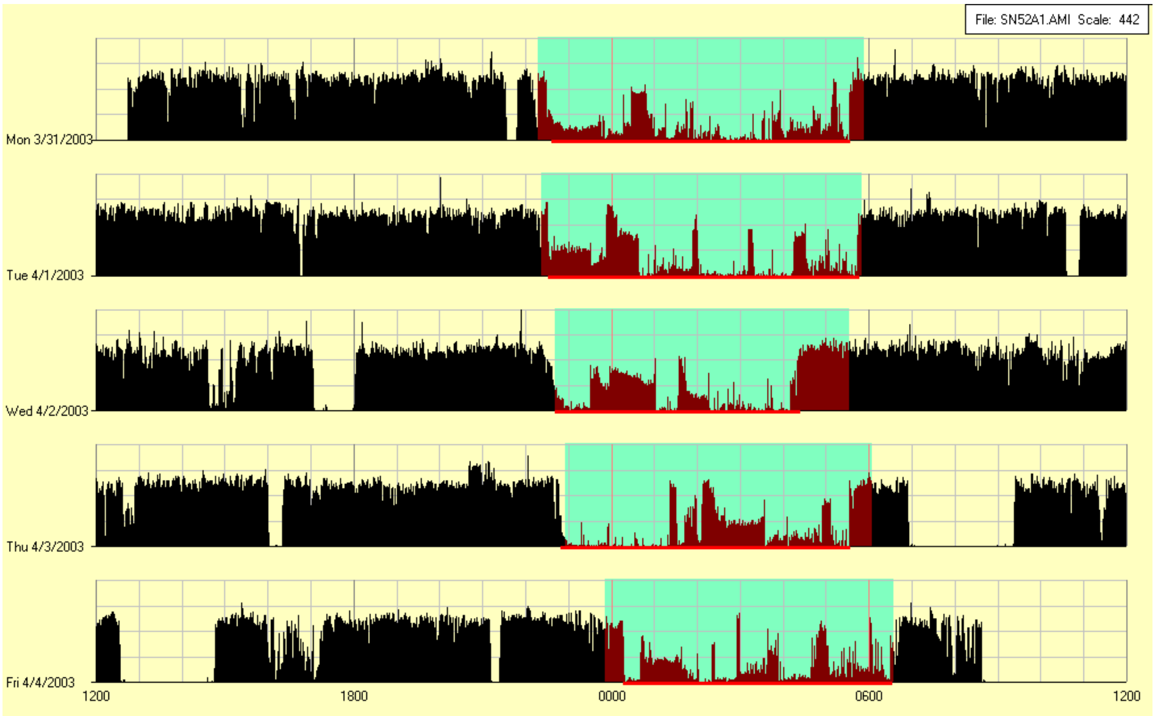
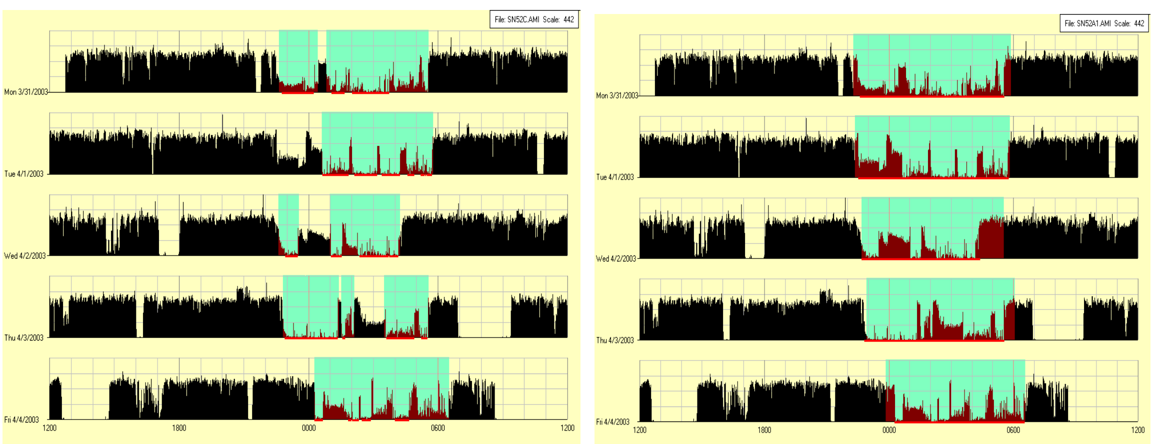


Figure 42. Actigraph Data Trimmed Using PDA Event Log



Trimmed Using Standard Method **Trimmed with PDA Log**

Figure 43. Side By Side Comparison of Actigraph Data

We imported the data from both methods into FAST schedules to model participant 52's predicted effectiveness. Figure 44 shows the FAST model of the Actigraph trimmed using the standard method and Figure 45 shows the FAST model using the PDA log to trim the data. The red line indicates the sleep reservoir as it is depleted and refilled according to the sleep/wake epochs. Figure 46 shows a side by side comparison of the FAST models. The modeled effectiveness of the two is decisively different. The additional sleep coded using the PDA log and the testament of the participant immediately after the data had been collected to verify accuracy accounts for a much higher predicted effectiveness level. Without any log, the model indicates predicted effectiveness far below acceptable levels. Though it appeared from his raw Actigraph data that participant 52 did not get much rest, according to his report, he did. This report made by the participant is his subjective account. However, the assumptions made by the researcher without reference to a log are also subjective and arguably less accurate. Subsequent examination of the Actigraph used by participant 52 showed that the device needed factory calibration.

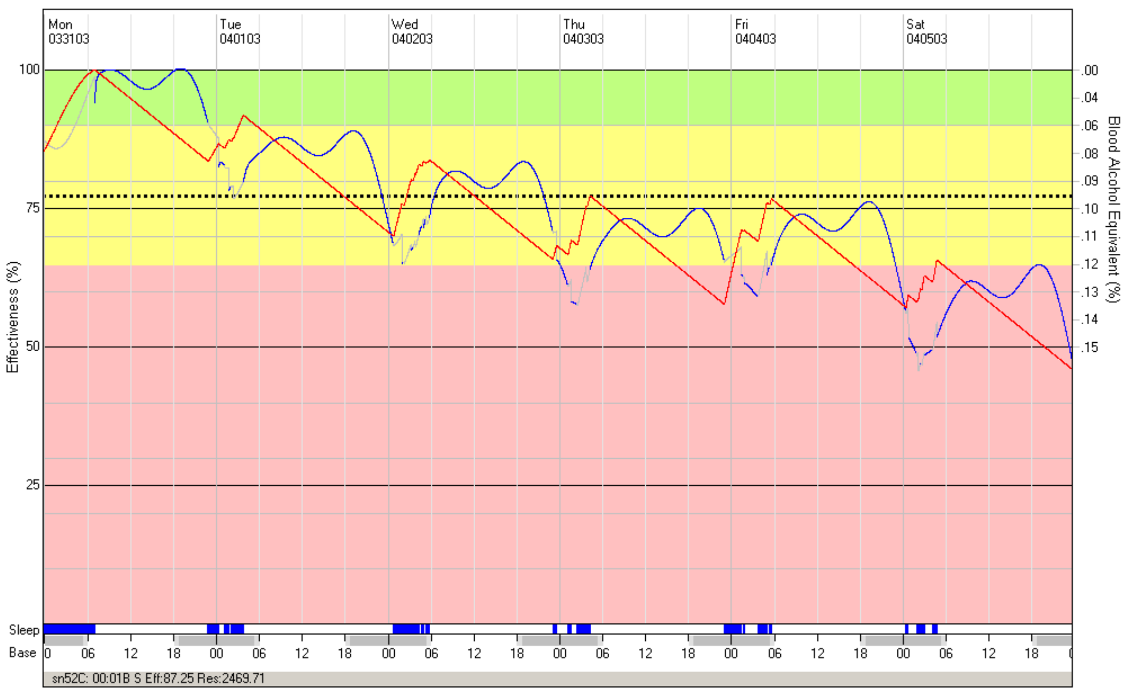


Figure 44. FAST Model without a Log

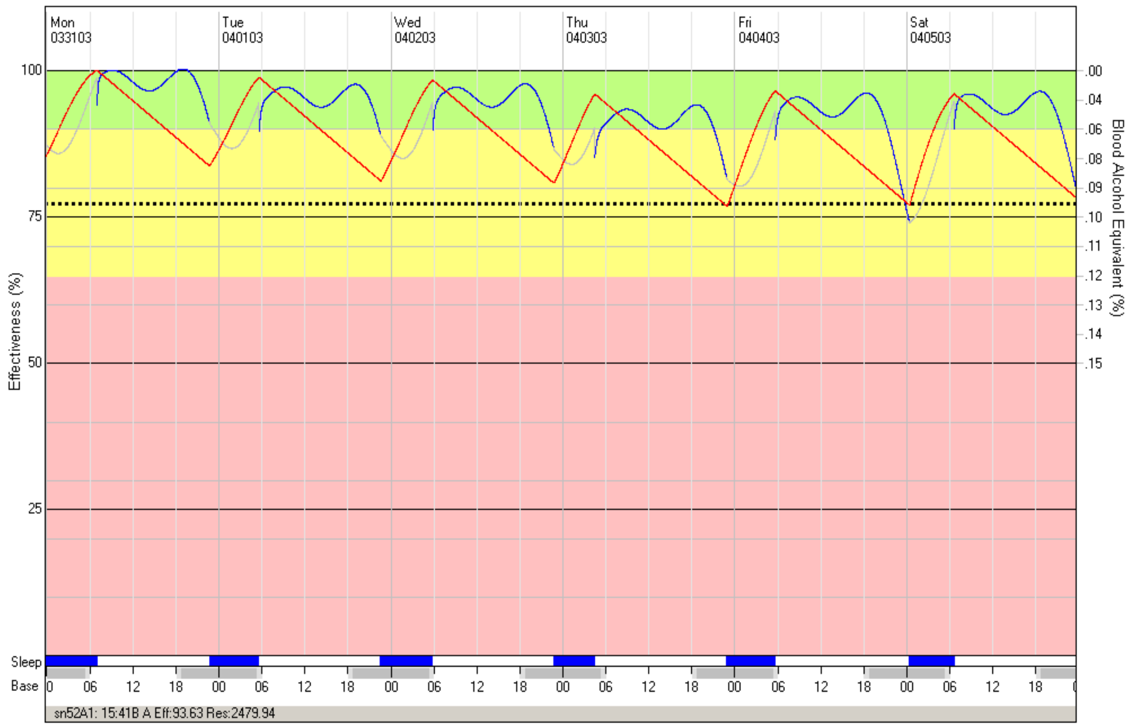
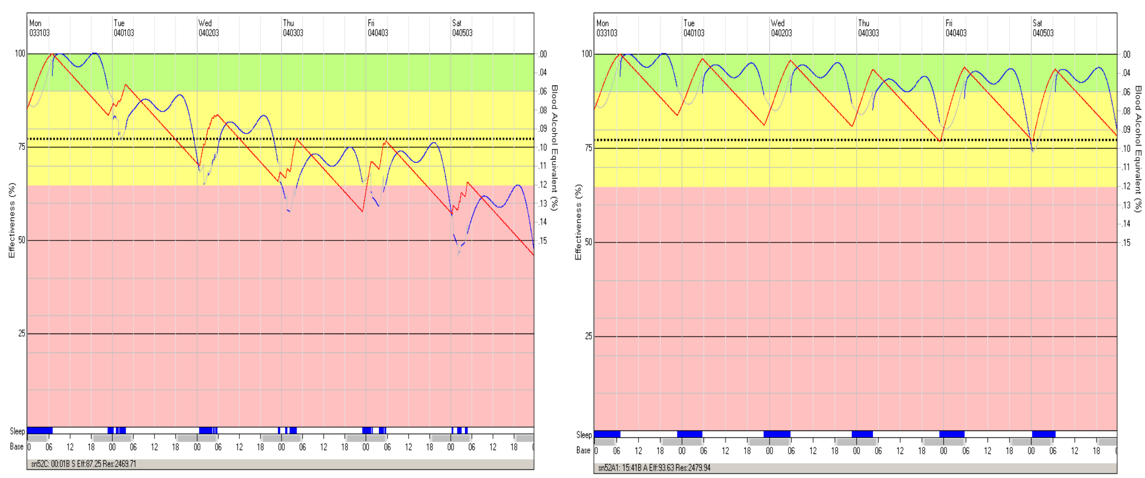


Figure 45. FAST Model with a PDA Log



Trimmed Using Standard Method **Trimmed with PDA Log**

Figure 46. Side By Side Comparison of FAST Models

Because our focus during the validation study was on collecting and storing data efficiently, we did not concentrate on the actual fatigue data as sleep researchers would have. Had we been interested in answering fatigue related questions, we could have conducted routine data downloads of Actigraph and log data and conducted quick analysis to ensure participants are logging events effectively. Using the old method, the time it took researchers to verify Actigraph data with the log data made this comparison impossible to do while on site without interrupting the study. The addition of the PDA log allows researchers to conduct this data verification between Actigraph data and logged events very easily. Any issues noted by the research team can be resolved immediately with the participant thus increasing the accuracy of the analysis.

2. PDA Issues

As part of our reengineering research, we evaluated various PDA handhelds and chose the Handspring TREO for our reengineered process. The laptops we used were equipped with Universal Serial Bus (USB) ports. When comparing ease of using the HotSync function, the Handspring versus the Palm products we evaluated seemed easier to use. Because the HanDBase and ARES software work with any PDA using the Palm OS, however, the process was not dependent on the PDA model. When we chose OIS as our validation study location, we understood that students and cadre were issued Palm PDAs upon arrival. Because we had not yet bought PDAs for HSIL, we decided to use the participants' Palms. We requested from OIS a sample Palm PDA so we could load and test our software to ensure compatibility. A Palm m100 arrived and although the display was black and white, all software seemed compatible. The Palm m100 cradle used a serial connector to the laptop for HotSync functions. When we arrived on site, we found that all participants were using the Palm V version of PDAs. When we tried to perform a HotSync function with our laptop using the Universal Serial Bus (USB) connection from the Palm V cradle to the laptop and Palm Desktop software, there were errors that could only be corrected by uninstalling and reinstalling the Palm software. Even after this, we experienced occasional HotSync errors with the Palm V using the USB port. Additionally, we had to spend hours configuring the Palm V's with the data collection software the evening before collection began. To avoid corruption of the participants' saved information on their PDAs, we chose to use their PDA names they had established and deviate from our process' naming convention (e.g., HSIL1, HSIL2, etc.). This caused us to have to change the repository database PDA STATUS table and populate it with the OIS PDA names. Because many participants used their last name as their PDA name, this collected data became sensitive since the HSIL policy prohibits storing any operational data with information identifying the participants other than their participant ID number. In order to store the data on the HSIL server, we had to delete these PDA names.

We recommend for future studies that the HSIL purchase 30 of the Handspring TREO models. When installing each PDA on the HSIL operational study laptop we recommend that PDAs be named according to our naming convention: HSIL1 through HSIL30. Each should be loaded with the HanDBase and ARES software. Additionally, we recommend loading the Sleep Log Template and its accompanying input form created with HanDBase software onto each PDA. For both the log and the ARES programs, the participant ID numbers should be added. These ID numbers should correspond to the PDA number. For example, on the PDA named HSIL1, the ARES registered user should be 01 and the "ID#" field on the log form should be 01. This way, all data downloaded from ARES and the event log programs during the HotSync function will be appropriately marked with a participant ID number that corresponds to the PDA ID in the Study Repository database.

In the event that participants are already issued PDAs from a U.S. governmental agency, we recommend that the research team attempt to accommodate the participants and use their issued PDAs so as not to further inconvenience the participants by requiring them to carry a second PDA during the data collection phase. In this case, it is essential that the research team acquire a sample of the PDA model used by the participants to ensure compatibility with both software and hardware. Additionally, the research team should allow enough time after arrival on site and prior to data collection to configure the participants' PDAs accordingly. Finally, the research team must ensure that the data saved from each PDA after each HotSync under the Palm directory on the laptop is erased and any identifying PDA ID names in the Study Repository database are erased as well to protect the participants' identity.

Despite the technical obstacles, the use of PDAs undoubtedly improves the "AS-IS" process. Whether using the PDAs from the HSIL or participants' PDAs, the ability to collect event log data and ARES data provides a tremendous advantage to the research team.

3. Actigraph Issues

Collecting actigraphy using the Actigraph and associated software posed unique challenges. Issues involving the Actigraph watches themselves as well as observations of other hardware and software became apparent to us during the study.

The Actigraph watch itself was bulky for the participants as they noted on their exit surveys; some cadre, unaware of the study, required the student participants to remove their Actigraphs for inspections. This resulted in a few participants failing to put the watch back on for several hours. A smaller more watch-like Actigraph with long battery life and low failure rates would clearly be better suited for field studies.

The interface box for the Actigraph requires a serial port connection and is not available for use with a USB connector. Because many laptops are no longer being made with serial ports, this may become an issue in the future. In a similar incompatibility issue, the software accompanying the watches from the manufacturer is a DOS based program that will not run on any Windows Operating System higher than Windows 95. The Act Millennium software offered by AMI, the marketing company of the Actigraph watches, as a Windows alternative is compatible with Windows XP. However, the initialization of and downloading of data from the watches are not intuitive processes. Researchers must be very familiar with the configuration settings of this software prior to collecting data.

Once the raw data have been downloaded using the interface unit and Act Millennium, they are saved as a .DAT file and then saved as an .AMI file to allow Action W software to read the data. Once trimmed in Action W, the data file has to be saved as an .EBE file to be read with FAST. After the research team has built a schedule in FAST covering the collection period, the .EBE file is imported into the schedule. After it has been "cleaned" in FAST, the data are again saved with a .FAS extension so it can be opened as a schedule in the future. Because of the unique data formats for these programs, the data could not be saved in the database for export. Instead, all versions of data with unique file extensions were saved in the same folder as the database on the web server. We tried to save the hyperlink to this folder location in the database but the files could not be associated with the programs to open automatically. Once a file is saved from Act Millennium as an .AMI file for Action W for example, we could not double click on that file and have Action W open and load the data. This process of opening programs, manipulating data, saving in new file formats to new locations on the server proved to be tedious and cumbersome. This inefficiency caused delays in preparing data for analysis that could easily be overcome by allowing import and export of universal data formats in all of the programs.

To ensure data integrity, researchers must be familiar with Act Millennium, Action W, and FAST software programs well before the data collection phase begins. Even with a comprehensive understanding, the process for tracking raw and "cleaned" data files quickly becomes overwhelming to the inexperienced researcher.

4. ARES Issues

Use of the ARES test battery requires researchers to plan for a significant increase in PDA power usage, unforeseen PDA system failures and unique data storage requirements. Despite some difficulties encountered using ARES software, the data from the performance tests were collected and the use of ARES is now a viable metric available for future studies.

Taking the ARES tests battery drains the PDA power rather quickly. As a result, researchers must be sure to remind participants to charge their PDAs daily. If participants' PDAs require disposable batteries, it is recommended that the research team maintain an adequate supply of these batteries on hand throughout the entire data collection period.

As a result of a bug in the ARES software, two PDAs locked up during the OIS study. The data in one device was unaffected because the participant brought the PDA to us and we initiated a soft reset. However, the data in the second device was lost because the participant inadvertently initiated a hard reset. Fortunately, it was on the first day of collection so only data one set of ARES data was lost. For future studies, researchers must obtain the latest version of ARES software to minimize the risk of bugs and ensure participants are aware of hard and soft reset procedures for PDAs in the event there is a problem. It is also recommended that short procedure cards be inserted into the PDA cases provided for the study. This card can contain contact information for researchers, soft reset procedures, and brief "how-to" instructions for completing ARES tests and logging events.

When downloading ARES data, there are two means available to the researcher. First, the desktop Data Manager program can be opened while the PDA is connected to the computer and the database file can be directly loaded into Data Manager. The second method is by using the HotSync function. Because the log data also have to be downloaded from the PDA, the HotSync method is more convenient. Once the file is downloaded as C:\Palm\[PDA_Name]\ARSubjDB.PDB, the Data Manager program has to be opened and only from there can the researcher load this data file. The Data Manager Program will not accept any other .PDB file than one named ARSubjDB.PDB. Therefore, all of the ARES raw data files from the participants cannot be stored in the same folder. Additionally, because the files all have the same name, there is understandable confusion manipulating these files and copying and storing the data to the database. Additionally, once the raw data are consolidated in the ARES table in the database, it can no longer be loaded into Data Manager but only used in programs like MS Excel. This significantly hinders the research team by requiring them to track many storage locations for the same data.

Though our data has yet to be analyzed thoroughly, we are confident that collecting ARES data on the PDA is an option now available to HSIL researchers. Diligent monitoring of and acquiring the new releases of upgraded versions of ARES software is imperative as some of these obstacles may be resolved in later software versions.

F. CONCLUSION

The OIS Study served to validate the improvements made in the "TO-BE" process. The data collection techniques do streamline the process, making the data analysis more efficient and accurate. While some recommendations for particular hardware and software used must be considered, the results of this study show that progression from the “AS-IS” to the “TO-BE” process is not only feasible but necessary. Using the reengineered system will allow more studies to be conducted annually with more valuable analysis due to better accuracy. Additionally, the storage repository allows a significant capability of conducting meta-analyses whose value has yet to be realized. The importance of fatigue research to the military, in particular, demands this immediate change from the current process to the reengineered one.

VII. CONCLUSIONS

A. SUMMARY DISCUSSION

The tremendous challenges faced by scientists conducting human research are further magnified when research is moved from the controlled laboratory to the field environment required by operational research. In the particular field of human performance and fatigue research, the unique intricacies of data collection represent some of the most complex in the field of human research. Serving as a Proof of Concept for a representative human research process, the process of conducting human performance and fatigue research at the HSIL at NPS was used to substantiate effective data collection and storage techniques. Applying current information technologies, we were able to demonstrate a significant improvement in productivity from the current "AS-IS" process to the reengineered "TO-BE" process. The methods used in this Proof of Concept could be applied to many data collection and storage processes in the broader field of human research thus refining the effectiveness of operational studies as researchers as they strive to improve human performance.

Using a three-tiered approach in the redesign, various graphical user interface means were utilized to collect and store data in a relational database housed on a NPS web server. Replacing paper surveys, web surveys and PDA-based input forms were incorporated to collect participant data. Similarly, database forms were designed to allow researchers to record details of a particular study. A PDA–based version of human performance software was used to collect performance data while wrist activity monitors containing accelerometers recorded participant activity levels. The database served not only as a storage facility to organize and maintain the collected data but also provided the research team with a standardized method to track their entire research process. As a result of the insertion of various information technologies, the reengineered process included automating current sub-processes and tasks and more importantly enabling new processes to be incorporated. With the conservatively estimated ROK improvement from 12% realized by the current process to 26% offered by the reengineered process, researchers at the HSIL at NPS will be able to conduct more studies per year while each study produces more accurate data analysis results. Additionally, the standardized storage means provided in the "TO-BE" process enables researchers to conduct meta-analysis; a capability not possible with the "AS-IS" process.

B. RECOMMENDATIONS

Because reengineering is, in itself, an iterative process, the prototype system developed for this Proof of Concept was the first step. Near-term initiatives taken at the HSIL at NPS to implement this redesign will result in greater overall improvement to the process. Efforts made to increase compatibility between systems by human performance and fatigue research hardware and software developers will further improve not only the process at NPS but the more extensive field of human performance and fatigue research. Finally, to transform the impact human research has on improving human performance under constraining conditions, system developers can take steps to design interoperable and unobtrusive collection means that allow for immediate analysis of human systems thus providing decision makers with the feedback required to optimize human resources.

1. Near-Term Initiatives to Improve the Process at the HSIL at NPS

In order to capitalize on the reengineering effort, it is necessary for the HSIL to employ an IT professional to implement the prototype system described in the "TO-BE" process and provide adequate system maintenance. This thesis serves as a guide for the research team, including the additional IT professional, at the HSIL to package a "How-To" type toolkit for future researchers to utilize when conducting field studies. The range of techniques for data collection extend beyond the methods used in this Proof of Concept system and each should be modeled to provide researchers an inventory of types of data to collect and the instructions and means to collect each in various operational environments. Secondly, templates should be created for each additional data collection method available to the HSIL researchers but not used in this Proof of Concept. Finally, a web-based feedback form should be created to capture the techniques used by research teams including both successful and unsuccessful trials. This cumulative feedback repository will include the data and analysis of all studies conducted at NPS and should capture all lessons learned by each research team thus creating a venue for continual improvement of human performance and fatigue research processes at NPS. This transfer of corporate knowledge to IT resources will provide future research teams an invaluable source of information allowing them to maximize the potential effects of their research on human performance.

2. Immediate Improvements to Human Performance and Fatigue Research Hardware and Software

Though current hardware and software developments in the field of human performance and fatigue research have only recently made operational studies possible, straightforward improvements to the existing hardware and software could have a tremendous impact on the productivity of the human performance and fatigue research. Storing data from various data collection media into compatible formats will drastically reduce the time and effort required of researchers to prepare their data for analysis. Further, an interface application to provide one point from which the researcher can access all software programs would ease the burdens associated with data "cleaning" thus allowing more time to spend on analyzing the collected data. This application should include the tools required to download, "clean," and analyze data as well as the means to efficiently both store the data and published the analysis. A more far reaching, yet attainable, goal should be to create a single suite of hardware and software that allows researchers to choose from an inventory of unobtrusive data collection media required for their research and easily tailor that media to fit the operational constraints of their specific data collection effort. This data collection means should incorporate wireless technological advances to allow data transfer without human intervention thus further increasing accuracy and saving time. The suite should also provide researchers with a variety of analysis tools to enable more comprehensive thus more revealing analysis. As new hardware monitoring devices are designed for human performance and fatigue research, they must be developed with system interoperability in mind.

3. Long Term Designs for Human Research Product Developers

To reach beyond data collection and analysis by offering solutions to mitigate obstacles, developers in the field of human research can make a tremendous impact toward improving the human condition. With the continual development of biomedical monitoring devices, developers can design products that not only monitor various human systems but offer self-analyzing feedback of the particular system's performance. From these various human system sensors as well as environmental monitoring media, developers will be able to create systems to evaluate the feedback and provide recommendations for physical or behavioral modifications to improve human performance. As a result of their complexity, humans provide invaluable and often irreplaceable additions to many processes. Optimizing human performance under constrained conditions is the goal of industry leaders and military commanders alike. Focusing human research product development on this goal, researchers will have the tools required to offer leaders options for resolving conflicts that inhibit optimal human performance.

APPENDIX A. KVA "AS-IS" ROK

ROK Calculations Page 1: "AS-IS" Part 1

"AS-IS" Process: Conducting Fatigue Studies

Sub Processes	Activities	Tasks	Unit	Learning Time	%IT	IT Learning Time	Number of Attempted Executions	Number of Successful Executions	Total Learning Time per Execution	Weighted Learning Time	Cycle Time	Labor Cost per Unit	Total Labor	ROK
Collect Data														
	Train Team													
		Train Research Team	Hrs	140	0%	0	1	1	140	140	90	1980	1980	7.1%
	Prepare Data													
		Design Study	Hrs	20	0%	0	1	1	20	20	4	88	88	22.7%
		Identify Funding Requirements	Hrs	6	0%	0	1	1	6	6	3	66	66	9.1%
		Create and type Demographic/Study Survey	Hrs	15	0%	0	1	1	15	15	12	264	264	5.7%
		Create and type Activity, Temperature, Sleep Log	Hrs	15	0%	0	1	1	15	15	12	264	264	5.7%
		Type Lark and Owl Survey	Hrs	1	0%	0	1	1	1	1	0.5	11	11	9.1%
		Type Consent Forms	Hrs	1	0%	0	1	1	1	1	0.5	11	11	9.1%
		Type IRB Proposal	Hrs	5	0%	0	1	1	5	5	2	44	44	11.4%
	Prepare Equipment													
		Initialize Watches	Hrs	2	80%	1.6	25	20	3.6	72	0.25	5.5	138	52.4%
		Obtain thermometers	Hrs	1	0%	0	1	1	1	1	0.5	11	11	9.1%
		Copy Logs Surveys Forms	Hrs	1	0%	0	1	1	1	1	0.5	11	11	9.1%
	ID Participants													
		Recruit Volunteers	Hrs	5	0%	0	1	1	5	5	16	352	352	1.4%
		Fillout Consent forms	Hrs	1	0%	0	1	1	1	1	0.5	11	11	9.1%
	Distribute and Collect													
		Explain Instructions for Completing Surveys	Hrs	1	0%	0	1	1	1	1	0.25	5.5	6	18.2%
		Explain Instr Wear/Use Equipment & Complt Logs	Hrs	2	0%	0	1	1	2	2	0.5	11	11	18.2%
		Collect Completed Surveys and Logs	Hrs	1	0%	0	1	1	1	1	0.25	5.5	6	18.2%
		Collect Watches	Hrs	1	0%	0	1	1	1	1	0.25	5.5	6	18.2%
		Collect and Clean Thermometers	Hrs	1	0%	0	1	1	1	1	1	22	22	4.5%
										289			3300	8.8%

NOTE:
Learning Time - the number of hours required to learn how to execute a task.
%IT - estimated amount of knowledge contained in IT systems that support the task
IT Learning Time = Learning Time X %IT
Number of Attempted Executions - Number of times a task is performed. If a task has to be repeated for each participant, for example, than this will equal the number of recruited participants.
Number of Successful Executions - Number of times a task is performed that results in data used in the study. If there are 25 participants initially recruited for the study but data for only 20 are used, than the number of successsful executions would be 20.
Total Learning Time Per Execution = Learning Time + IT Learning Time
Weighted Learning Time = Total Learning Time X Number of Successful Executions
Cycle Time is the number of hours required to execute the task.
Labor Cost per Unit = the hourly cost rate (conservatively estimated at $22/hour) X Cycle Time
Total Labor = Labor Cost per Unit X Number of Attempted Executions
ROK = Weighted Learning Time / Total Labor

Using the KVA methodology in an economic context if this were a revenue generating organization, the amount of knowledge (weighted learning time) allocated to each task would be calculated. Then, the annual revenue would be allocated based on the amount of knowledge embedded in the task. The ROK would then be calculated as the allocated revenue divided by the cost to use the knowledge. Because this process did not generate revenue, we adapted the theory of KVA and applied it to calculate our own ROK percentage.

ROK Calculations Page 1: "AS-IS" Part 1

"AS-IS" Process: Conducting Fatigue Studies

Sub Processes	Activities	Tasks	Unit	Learning Time	%IT	IT Learning Time	Number of Attempted Executions	Number of Successful Executions	Total Learning Time per Execution	Weighted Learning Time	Cycle Time	Labor Cost per Unit	Total Labor	ROK
Collect Data														
	Train Team													
		Train Research Team	Hrs	140	0%	0	1	1	140	140	90	1980	1980	7.1%
	Prepare Data													
		Design Study	Hrs	20	0%	0	1	1	20	20	4	88	88	22.7%
		Identify Funding Requirements	Hrs	6	0%	0	1	1	6	6	3	66	66	9.1%
		Create and type Demographic/Study Survey	Hrs	15	0%	0	1	1	15	15	12	264	264	5.7%
		Create and type Activity, Temperature, Sleep Log	Hrs	15	0%	0	1	1	15	15	12	264	264	5.7%
		Type Lark and Owl Survey	Hrs	1	0%	0	1	1	1	1	0.5	11	11	9.1%
		Type Consent Forms	Hrs	1	0%	0	1	1	1	1	0.5	11	11	9.1%
		Type IRB Proposal	Hrs	5	0%	0	1	1	5	5	2	44	44	11.4%
	Prepare Equipment													
		Initialize Watches	Hrs	2	80%	1.6	25	20	3.6	72	0.25	5.5	138	52.4%
		Obtain thermometers	Hrs	1	0%	0	1	1	1	1	0.5	11	11	9.1%
		Copy Logs Surveys Forms	Hrs	1	0%	0	1	1	1	1	0.5	11	11	9.1%
	ID Participants													
		Recruit Volunteers	Hrs	5	0%	0	1	1	5	5	16	352	352	1.4%
		Fillout Consent forms	Hrs	1	0%	0	1	1	1	1	0.5	11	11	9.1%
	Distribute and Collect													
		Explain Instructions for Completing Surveys	Hrs	1	0%	0	1	1	1	1	0.25	5.5	6	18.2%
		Explain Instr Wear/Use Equipment & Complt Logs	Hrs	2	0%	0	1	1	2	2	0.5	11	11	18.2%
		Collect Completed Surveys and Logs	Hrs	1	0%	0	1	1	1	1	0.25	5.5	6	18.2%
		Collect Watches	Hrs	1	0%	0	1	1	1	1	0.25	5.5	6	18.2%
		Collect and Clean Thermometers	Hrs	1	0%	0	1	1	1	1	1	22	22	4.5%
										289			3300	8.8%

NOTE:
Learning Time - the number of hours required to learn how to execute a task.
%IT - estimated amount of knowledge contained in IT systems that support the task
IT Learning Time = Learning Time X %IT
Number of Attempted Executions - Number of times a task is performed. If a task has to be repeated for each participant, for example, than this will equal the number of recruited participants.
Number of Successful Executions - Number of times a task is performed that results in data used in the study. If there are 25 participants initially recruited for the study but data for only 20 are used, than the number of successsful executions would be 20.
Total Learning Time Per Execution = Learning Time + IT Learning Time
Weighted Learning Time = Total Learning Time X Number of Successful Executions
Cycle Time is the number of hours required to execute the task.
Labor Cost per Unit = the hourly cost rate (conservatively estimated at $22/hour) X Cycle Time
Total Labor = Labor Cost per Unit X Number of Attempted Executions
ROK = Weighted Learning Time / Total Labor

Using the KVA methodology in an economic context if this were a revenue generating organization, the amount of knowledge (weighted learning time) allocated to each task would be calculated. Then, the annual revenue would be allocated based on the amount of knowledge embedded in the task. The ROK would then be calculated as the allocated revenue divided by the cost to use the knowledge. Because this process did not generate revenue, we adapted the theory of KVA and applied it to calculate our own ROK percentage.

ROK Calculations Page 2: "AS-IS" Part 2

"AS-IS" Process: Conducting Fatigue Studies

Sub Processes	Activities	Tasks	Unit	Learning Time	%IT	IT Learning Time	Number of Attempted Executions	Number of Successful Executions	Total Learning Time per Execution	Weighted Learning Time	Cycle Time	Labor Cost per Unit	Total Labor	ROK
Prepare for Analysis														
	Input Data to Excel from Surveys and Logs													
		Manually Enter Study Data	Hrs	2	50%	1	25	20	3	60	0.25	5.5	138	43.6%
		Manually Enter Log Data	Hrs	2	50%	1	25	20	3	60	2	44	1100	5.5%
		Manually enter Lark and Owl Data	Hrs	1	50%	0.5	25	20	1.5	30	0.5	11	275	10.9%
	Clean Excel Paper Data													
		Compare Surveys and Spread	Hrs	1	20%	0.2	25	20	1.2	24	4	88	2200	1.1%
	Download Actigraphs													
		Download Data from Watches	Hrs	2	80%	1.6	25	20	3.6	72	0.25	5.5	138	52.4%
		Save watch data for Act W	Hrs	2	80%	1.6	25	20	3.6	72	0.25	5.5	138	52.4%
	Clean Actigraph Data													
		Import watch data to Action W	Hrs	2	80%	1.6	25	20	3.6	72	0.25	5.5	138	52.4%
		Compare Action W with Log	Hrs	4	20%	0.8	25	20	4.8	96	0.5	11	275	34.9%
		Code data as sleep wake	Hrs	2	30%	0.6	25	20	2.6	52	0.3	6.6	165	31.5%
		Identify Down Period	Hrs	1	30%	0.3	25	20	1.3	26	0.25	5.5	138	18.9%
		ID errors in Action W file	Hrs	2	20%	0.4	25	20	2.4	48	0.5	11	275	17.5%
		Generate sleep statistics	Hrs	3	50%	1.5	25	20	4.5	90	0.5	11	275	32.7%
		Save for import to FAST	Hrs	1	80%	0.8	25	20	1.8	36	0.25	5.5	138	26.2%
	Input to Excel from Action W													
		Manually enter sleep statistics to Excel	Hrs	2	50%	1	25	20	3	60	1	22	550	10.9%
	Analyze with FAST													
		Define schedule for FAST	Hrs	4	50%	2	25	20	6	120	0.5	11	275	43.6%
		Import ebe to FAST	Hrs	1	50%	0.5	25	20	1.5	30	0.25	5.5	138	21.8%
		Identify Sleep Effectiveness	Hrs	4	50%	2	25	20	6	120	1	22	550	21.8%
	Input Data to Excel from FAST													
		Manually enter effectiveness	Hrs	1	50%	0.5	25	20	1.5	30	0.5	11	275	10.9%
		Compare FAST to survey data	Hrs	2	50%	1	25	20	3	60	2	44	1100	5.5%
										1158			8278	14.0%
Analyze and Publish														
	Import data to SPSS													
		Import data to SPSS	Hrs	2	50%	1	3	3	3	9	1	22	66	13.6%
	Conduct Data Analysis using SPSS													
		Conduct descriptive analysis	Hrs	720	20%	144	1	1	864	864	240	5280	5280	16.4%
	Publish Analysis													
		Write Thesis	Hrs	240	20%	48	1	1	288	288	112	2464	4846	5.9%
										1161			10192	11.4%
							TOTAL "AS-IS" ROK			2319			18470	12.6%

ROK Calculations Page 3: "TO-BE" Part 1

"TO-BE" Process: Conducting Fatigue Studies

Sub Processes	Activities	Tasks	Unit	Learning Time	% IT	IT Learning Time	Number of Attempted Executions	Number of Successful Executions	Total Learning Time per Execution	Weighted Learning Time	Cycle Time	Labor Cost per Unit	Total Labor	ROK
Collect Data														
	Train Team													
		Train Research Team	Hrs	140	20%	28	2	2	168	336	45	990	1980	16.97%
	Prepare Data													
		Design Study	Hrs	20	0%	0	2	2	20	40	4	88	176	22.73%
		Identify Funding Requirements	Hrs	6	0%	0	2	2	6	12	3	66	132	9.09%
		Modify Demographic/Study Survey on Web	Hrs	40	50%	20	2	2	60	120	3	66	132	90.91%
		Append Lark and Owl Survey to Webpage	Hrs	3	50%	1.5	2	2	4.5	9	1	22	44	20.45%
		Modify Study Database	Hrs	15	60%	9	2	2	24	48	4	88	176	27.27%
		Modify PDA Log	Hrs	16	40%	6.4	2	2	22.4	44.8	6	132	264	16.97%
		Type IRB Proposal	Hrs	5	0%	0	2	2	5	10	2	44	88	11.36%
	Prepare Equipment													
		Initialize Watches	Hrs	2	80%	1.6	50	50	3.6	180	0.25	5.5	275	65.45%
		Load PDAs with Log Software	Hrs	8	80%	6.4	50	50	14.4	720	0.25	5.5	275	261.82%
		Load PDAs with ARES Software	Hrs	3	80%	2.4	50	50	5.4	270	0.25	5.5	275	98.18%
		Print Consent Forms	Hrs	1	0%	0	2	2	1	2	0.5	11	22	9.09%
	ID Participants													
		Recruit Volunteers	Hrs	5	0%	0	2	2	5	10	8	176	352	2.84%
		Fillout Consent forms	Hrs	1	0%	0	2	2	1	2	0.5	11	22	9.09%
	Distribute and Collect													
		Explain Instr Wear/Use Equipment & Complt Logs	Hrs	2	0%	0	2	2	2	4	0.5	11	22	18.18%
		Collect Watches + PDAs	Hrs	1	0%	0	2	2	1	2	0.25	5.5	11	18.18%
										1809.8			4246	42.62%

NOTE:

In the sample period of one year, the "TO-BE" process can be conducted at least 2 times due to the effciencies of data collection and storage techniques. This is a conservative estimate.

ROK Calculations Page 4: "TO-BE" Part 2

"TO-BE" Process: Conducting Fatigue Studies

Sub Processes	Activities	Tasks	Unit	Learning Time	% IT	IT Learning Time	Number of Attempted Executions	Number of Successful Executions	Total Learning Time per Execution	Weighted Learning Time	Cycle Time	Labor Cost per Unit	Total Labor	ROK
Prepare for Analysis														
	Input Data to Excel from Surveys & Logs													
		Download PDA Log Data	Hrs	1	80%	0.8	50	50	1.8	90	0.25	5.5	275	32.73%
		Download PDA ARES Data	Hrs	1	80%	0.8	50	50	1.8	90	0.25	5.5	275	32.73%
		Clean Data and Upload to Database	Hrs	5	50%	2.5	50	50	7.5	375	0.5	11	550	68.18%
	Download Actigraphs													
		Download Data from Watches	Hrs	2	80%	1.6	50	50	3.6	180	0.25	5.5	275	65.45%
		Save watch data for Act W (in Database)	Hrs	3	80%	2.4	50	50	5.4	270	0.3	6.6	330	81.82%
	Clean Actigraph Data													
		Import watch data to Action W	Hrs	2	80%	1.6	50	50	3.6	180	0.25	5.5	275	65.45%
		Compare Action W with Log	Hrs	7	50%	3.5	50	50	10.5	525	0.5	11	550	95.45%
		Generate sleep statistics	Hrs	3	50%	1.5	50	50	4.5	225	0.5	11	550	40.91%
		Save for import to FAST (in Database)	Hrs	1	80%	0.8	50	50	1.8	90	0.3	6.6	330	27.27%
	Input to Excel from Action W													
		Manually enter sleep statistics to Excel	Hrs	2	50%	1	50	50	3	150	1	22	1100	13.64%
		Save Sleep Statistics (in Database)	Hrs	1	80%	0.8	50	50	1.8	90	0.25	5.5	275	32.73%
	Analyze with FAST													
		Define schedule for FAST	Hrs	4	50%	2	50	50	6	300	0.5	11	550	54.55%
		Import ebe to FAST	Hrs	1	50%	0.5	50	50	1.5	75	0.25	5.5	275	27.27%
		Identify Sleep Effectiveness	Hrs	4	50%	2	50	50	6	300	1	22	1100	27.27%
	Input Data to Excel from FAST													
		Manually enter effectiveness to Excel	Hrs	1	50%	0.5	50	50	1.5	75	0.5	11	550	13.64%
		Save Sleep Effectiveness (in Database)	Hrs	1	80%	0.8	50	50	1.8	90	0.25	5.5	275	32.73%
		Compare FAST to survey data	Hrs	2	50%	1	50	50	3	150	2	44	2200	6.82%
										3075			9185	33.48%
Analyze and Publish														
	Import data to SPSS													
		Import data to SPSS	Hrs	2	50%	1	2	2	3	6	1.5	33	66	9.09%
	Conduct Data Analysis using SPSS													
		Conduct descriptive analysis	Hrs	720	20%	144	2	2	864	1728	240	5280	10560	16.36%
		Save Analyzed Data (in Database)	Hrs	3	80%	2.4	50	50	5.4	270	1	22	1100	24.55%
	Publish Analysis													
		Write Thesis	Hrs	240	20%	48	2	2	288	576	112	2464	4846	11.89%
										6885			32082	21.46%
							TOTAL "TO-BE" ROK			90			275	32.73%

ROK Calculations Page 5: "Dramatic Redesign" Part 1														
"Dramatic Redesign" Process: Conducting Fatigue Studies														
Sub Processes	Activities	Tasks	Unit	Learn Time	%IT	IT Learning Time	Number of Attempted Executions	Number of Successful Executions	Total Learning Time per Execution	Weighted Learning Time	Cycle Time	Labor Cost per Unit	Total Labor	ROK
Collect Data														
	Train Team													
		Train Research Team	Hrs	140	20%	28	150	150	168	25200	33.75	742.5	111375	23%
	Prepare Data										0			
		Design Study	Hrs	20	0%	0	150	150	20	3000	3	66	9900	30%
		Identify Funding Requirements	Hrs	6	0%	0	150	150	6	900	2.25	49.5	7425	12%
		Modify Demographic/Study Survey on We	Hrs	40	0%	0	150	150	40	6000	2.25	49.5	7425	81%
		Append Lark and Owl Survey to Webpage	Hrs	3	0%	0	150	150	3	450	0.75	16.5	2475	18%
		Modify Study Database	Hrs	15	60%	9	150	150	24	3600	3	66	9900	36%
		Modify PDA Log	Hrs	16	40%	6.4	150	150	22.4	3360	4.5	99	14850	23%
		Type IRB Proposal	Hrs	5	0%	0	150	150	5	750	1.5	33	4950	15%
	Prepare Equipment										0			
		Initialize Watches	Hrs	2	80%	1.6	15000	15000	3.6	54000	0.188	4.125	61875	87%
		Load PDAs with Log Software	Hrs	8	80%	6.4	15000	15000	14.4	216000	0.188	4.125	61875	349%
		Load PDAs with ARES Software	Hrs	3	80%	2.4	15000	15000	5.4	81000	0.188	4.125	61875	131%
		Print Consent Forms	Hrs	1	0%	0	150	150	1	150	0.375	8.25	1238	12%
	ID Participants										0			
		Recruit Volunteers	Hrs	5	0%	0	150	150	5	750	8	88	13200	6%
		Fillout Consent forms	Hrs	1	0%	0	150	150	1	150	0.5	6	825	18%
	Distribute and Collect													
		Explain Instr Wear/Use Equipment & Comp	Hrs	2	0%	0	150	150	2	300	0.5	6	825	36%
		Collect Watches + PDAs	Hrs	1	0%	0	150	150	1	150	0.25	3	413	36%
										395760			370425	107%
Prepare for Analysis														
	Input Data to Excel from Surveys and Logs													
		Download PDA Log Data	Hrs	8	90%	7.2	15000	15000	15.2	228000	0.25	3	41250	553%
		Downlaod PDA ARES Data	Hrs	2	80%	1.6	15000	15000	3.6	54000	0.25	3	41250	131%
		Clean Data and Upload to Database	Hrs	5	50%	2.5	15000	15000	7.5	112500	0.5	6	82500	136%
	Download Actigraphs													
		Download Data from Watches	Hrs	2	80%	1.6	15000	15000	3.6	54000	0.25	3	41250	131%
		Save watch data for Act W (in Database)	Hrs	3	80%	2.4	15000	15000	5.4	81000	0.3	3	49500	164%
	Clean Actigraph Data													
		Import watch data to Action W	Hrs	2	80%	1.6	15000	15000	3.6	54000	0.188	4.125	61875	87%
		Compare Action W with Log	Hrs	7	50%	3.5	15000	15000	10.5	157500	0.375	8.25	123750	127%
		Generate sleep statistics	Hrs	3	50%	1.5	15000	15000	4.5	67500	0.375	8.25	123750	55%
		Save for import to FAST (in Database)	Hrs	1	80%	0.8	15000	15000	1.8	27000	0.225	4.95	74250	36%
	Input to Excel from Action W													
		Manually enter sleep statistics to Excel	Hrs	2	50%	1	15000	15000	3	45000	0.75	16.5	247500	18%
		Save Sleep Statistics (in Database)	Hrs	1	80%	0.8	15000	15000	1.8	27000	0.188	4.125	61875	44%
	Analyze with FAST													
		Define schedule for FAST	Hrs	4	50%	2	15000	15000	6	90000	0.375	8.25	123750	73%
		Import ebe to FAST	Hrs	1	50%	0.5	15000	15000	1.5	22500	0.188	4.125	61875	36%
		Identify Sleep Effectiveness	Hrs	4	50%	2	15000	15000	6	90000	0.75	16.5	247500	36%
	Input Data to Excel from FAST													
		Manually enter effectiveness to Excel	Hrs	1	50%	0.5	15000	15000	1.5	22500	0.375	8.25	123750	18%
		Save Sleep Effectiveness (in Database)	Hrs	1	80%	0.8	15000	15000	1.8	27000	0.188	4.125	61875	44%
		Compare FAST to survey data	Hrs	2	50%	1	15000	15000	3	45000	1.5	33	495000	9%
										1204500			2062500	58%
Analyze and Publish														
	Import data to SPSS													
		Import data to SPSS	Hrs	2	50%	1	150	150	3	450	1.125	24.75	3713	12%
	Conduct Data Analysis using SPSS													
		Conduct descriptive analysis	Hrs	720	20%	144	150	150	864	129600	180	3960	594000	22%
		Save Analyzed Data (in Database)	Hrs	3	80%	2.4	15000	15000	5.4	81000	0.75	16.5	247500	33%
	Publish Analysis													
		Write Thesis	Hrs	240	20%	48	150	150	288	43200	84	1848	277200	16%
										254250			1122413	23%
							TOTAL "DRASTIC" ROK			1854510			3555338	52%

ROK Calculations Page 6: Comparison of "AS-IS" to "TO-BE" to "Dramatic"

Process: NPS Executing Fatigue Studies

Sub Processes	Weighted Learning Time	Total Cost	As-Is ROK	To-Be ROK	Dramatic ROK
Collect Data	289	3300	9%		
	1810	4246		43%	
	395760	370425			107%
Prepare for Analysis	1158	8278	14%		
	3075	9185		33%	
	1204500	2062500			58%
Analyze and Publish	1161	10192	11%		
	6885	32082		21%	
	254250	1122413			23%
TOTAL	2608	21770	12%		
	11770	45513		26%	
	1854510	3555338			52%

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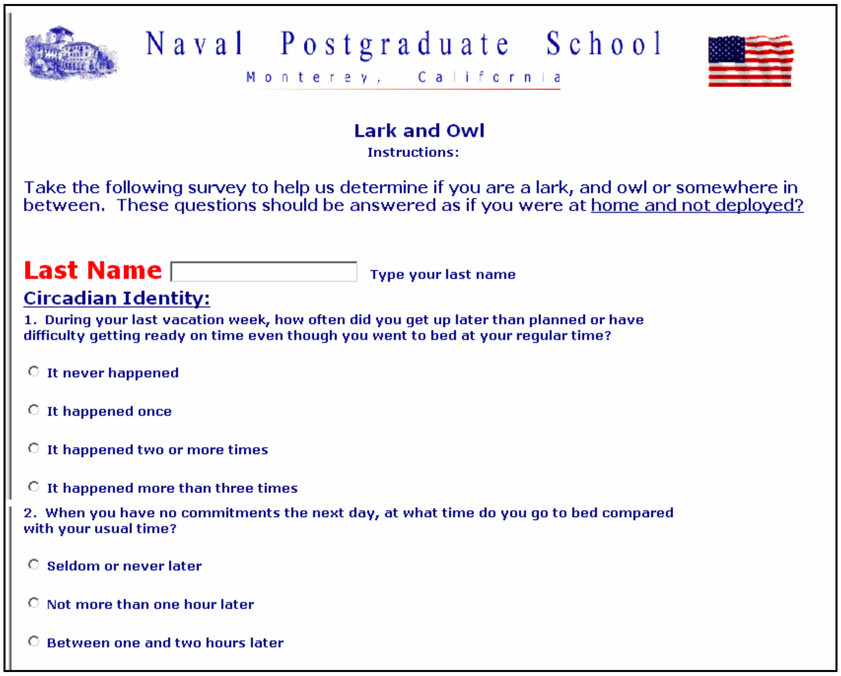
APPENDIX B. WEB SURVEY PROTOTYPES

Lark and Owl Web Survey



Naval Postgraduate School

Monterey, California

Lark and Owl

Instructions:

Take the following survey to help us determine if you are a lark, and owl or somewhere in between. These questions should be answered as if you were at home and not deployed?

Last Name Type your last name

Circadian Identity:

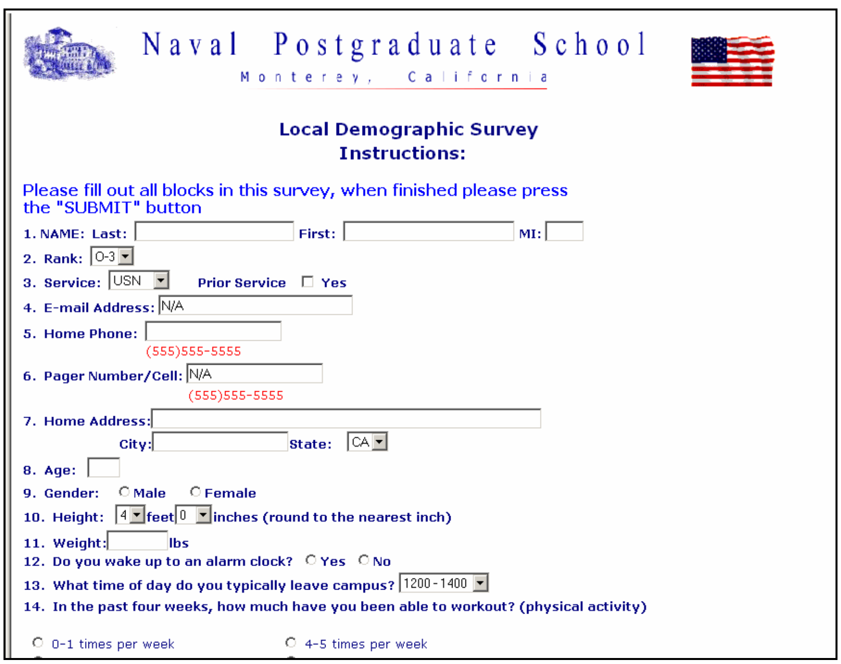
1. During your last vacation week, how often did you get up later than planned or have difficulty getting ready on time even though you went to bed at your regular time?

- It never happened
- It happened once
- It happened two or more times
- It happened more than three times

2. When you have no commitments the next day, at what time do you go to bed compared with your usual time?

- Seldom or never later
- Not more than one hour later
- Between one and two hours later

Demographic Web Survey Template



Naval Postgraduate School

Monterey, California

Local Demographic Survey

Instructions:

Please fill out all blocks in this survey, when finished please press the "SUBMIT" button

1. NAME: Last: First: MI:
2. Rank: O-3
3. Service: USN Prior Service Yes
4. E-mail Address: N/A
5. Home Phone: (555)555-5555
6. Pager Number/Cell: N/A (555)555-5555
7. Home Address: City: State: CA
8. Age:
9. Gender: Male Female
10. Height: 4 feet 0 inches (round to the nearest inch)
11. Weight: lbs
12. Do you wake up to an alarm clock? Yes No
13. What time of day do you typically leave campus? 1200 - 1400
14. In the past four weeks, how much have you been able to workout? (physical activity)

- 0-1 times per week
- 4-5 times per week

Morningness/Eveningness Scale

Directions: This scale is designed to help you identify a person's tendency toward a morning (lark) or evening (owl) circadian rhythm pattern.

1. During your last vacation week, how often did you get up later than planned or have difficulty getting ready on tie even though you went to bed at our regular time?

    A. It never happened
    B. It happened once
    C. It happened two or more times
    D. It happened more than three times

2. When you have no commitments the next day, at what time do you go to bed compared with your usual time?

    A. Seldom or never later
    B. Not more than one hour later
    C. Between one and two hours later
    D. More than two hours later

3. Suppose that you have decided to exercise twice a week with a friend. The only time your friend can make it is from 7:00 a.m. to 8:00 a.m., twice a week. Assume you decide to go at these times. Taking into account how you usually feel in the morning, how would you do?

    A. Very well
    B. Well
    C. Poorly
    D. Very Poorly

4. At what time in the evening do you usually start feeling tired and in need of sleep?

    A. 8:00 p.m. – 9:30 p.m.
    B. 9:31 p.m. – 10:45 p.m.
    C. 10:46 p.m. –12:30 a.m.
    D. 12:31 a.m. –1:45 a.m.
    E. 1:46 a.m. – 3:00 a.m.

5. Suppose that you were able to choose your own working hours. Assume that your job was interesting and paid according to results. Which one of the following 3-hour blocks would be your most preferred work time?

    A. 4:00 a.m. – 7:00 a.m.
    B. 7:00 a.m. – 10:00 a.m.

C. 11:00 a.m. – 2:00 p.m.
D. 4:00 p.m. – 7:00 p.m.
E. 9:00 p.m. – 12:00 Midnight.

6. One sometimes hears about "feeling best in the morning" or "feeling best in the evening" types of people. Which do you consider yourself?

A. Definitely a "morning" type
B. More a "morning" than an "evening" type
C. More an "evening" than a "morning" type
D. Definitely an "evening" type

SCORE GUIDE

Question No.	Answer	Score	Question No	Answer	Score
1	A	6	4	A	7
	B	5		B	6
	C	5		C	5
	D	4		D	4
				E	3
2	A	7	5	A	7
	B	6		B	6
	C	4		C	5
	D	3		D	4
				E	3
3	A	7	6	A	9
	B	6		B	7
	C	4		C	3
	D	3		D	1

SCORE SCALE

17 to 19	Extreme Owl
20 to 23	Moderate Owl
24 to 29	Mild Owl
30	Neither Owl nor Lark
31 to 36	Mild Lark
37 to 40	Moderate Lark
41 to 43	Extreme Lark

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APPENDIX C. STUDY REPOSITORY TEMPLATE DATABASE RELATIONSHIPS

Actigraph StatusActigraph

Actigraph Status			Actigraph
Actigraph ID	1	?	actigraphID

Attributes: Enforced
RelationshipType: One-To-Many

ParticipantActigraph

Participant			Actigraph
ParticipantID	1	?	participantID

Attributes: Enforced
RelationshipType: One-To-Many

ParticipantARES Data

Participant			ARES Data
ParticipantID	1	?	participantID

Attributes: Enforced
RelationshipType: One-To-Many

ParticipantCollected Equipment and Data

Participant			Collected Data and Equipment
ParticipantID	1	1	ParticipantID

Attributes: Unique, Enforced
RelationshipType: One-To-One

ParticipantLark and Owl

Participant			**Lark and Owl**
ParticipantID	1	?	ParticipantID

Attributes: Enforced
RelationshipType: One-To-Many

ParticipantLog

Participant			**Log**
ParticipantID	1	?	ParticipantID

Attributes: Enforced
RelationshipType: One-To-Many

ParticipantPDA

Participant			**PDA**
ParticipantID	1	?	participantID

Attributes: Enforced
RelationshipType: One-To-Many

PDA StatusPDA

PDA Status			**PDA**
PDA ID	1	?	PDA ID

Attributes: Enforced
RelationshipType: One-To-Many

Research TeamResearch_Team_Study

Research Team			**Research_Team_Study**
ResearcherID	1	?	ResearcherID

Attributes:	Enforced
RelationshipType:	One-To-Many

StudyParticipant

Study			**Participant**
StudyID	1	?	Study ID

Attributes:	Enforced
RelationshipType:	One-To-Many

StudyResearch_Team_Study

Study			**Research_Team_Study**
StudyID	1	?	StudyID

Attributes:	Enforced
RelationshipType:	One-To-Many

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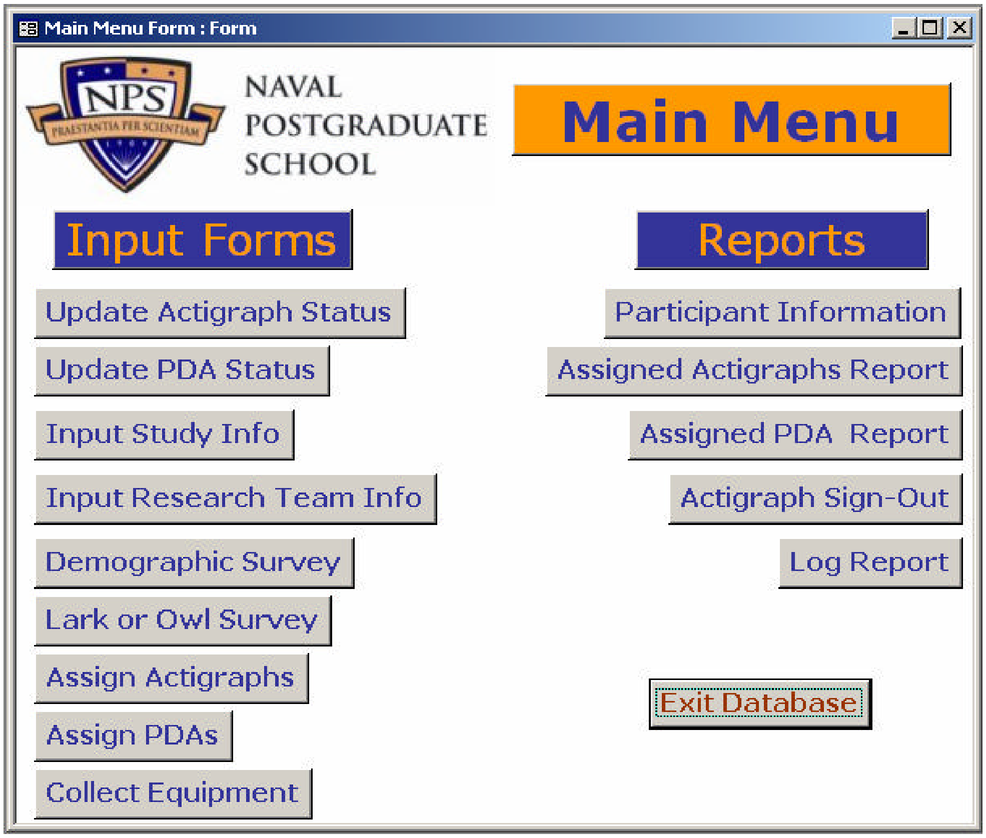
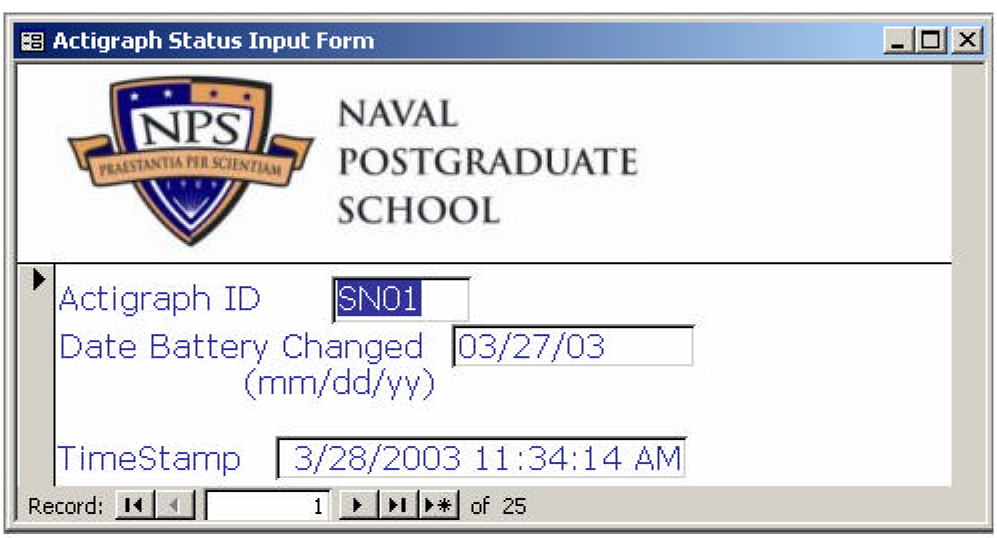
APPENDIX D. PROTOTYPE FORMS AND REPORTS FROM STUDY REPOSITORY TEMPLATE DATABASE

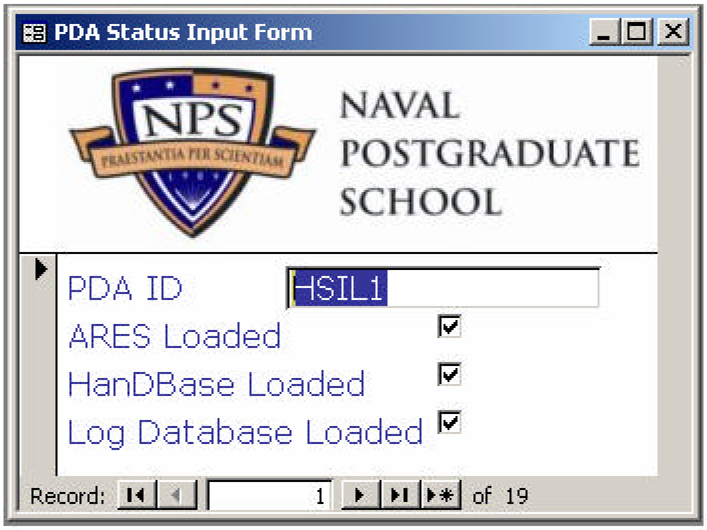
Main Menu Form



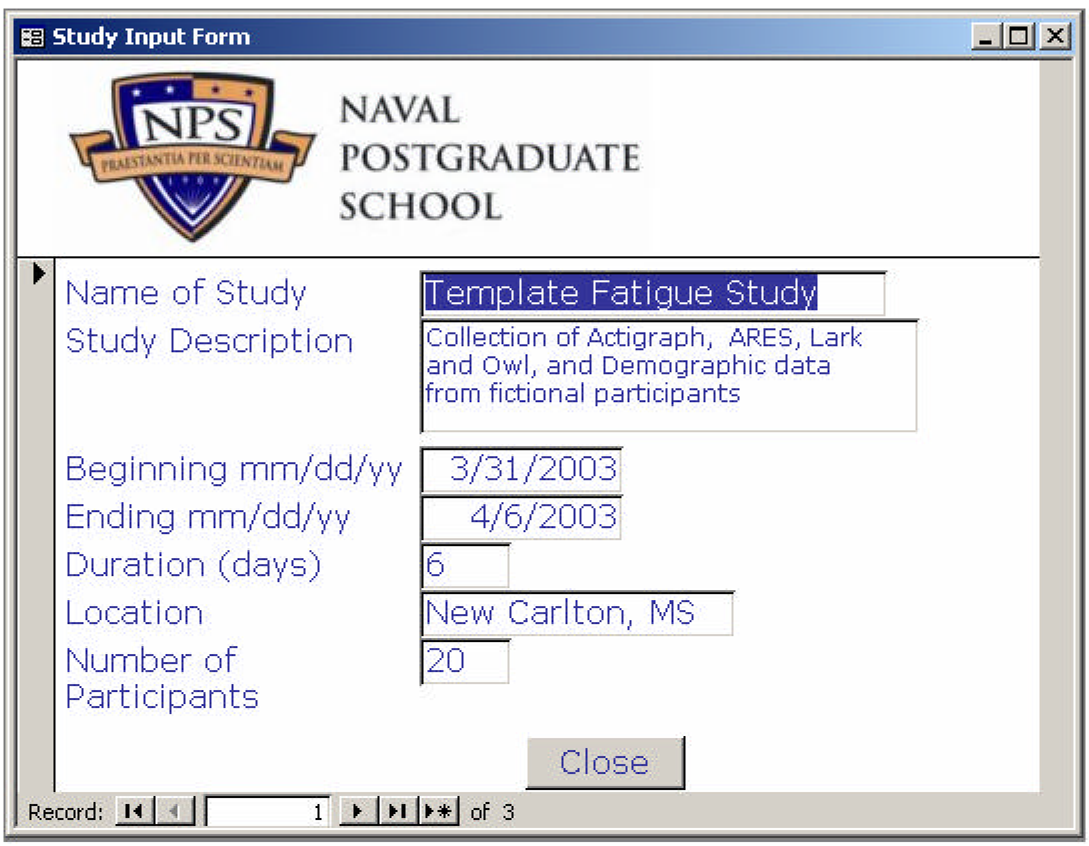
Actigraph Status Input Form



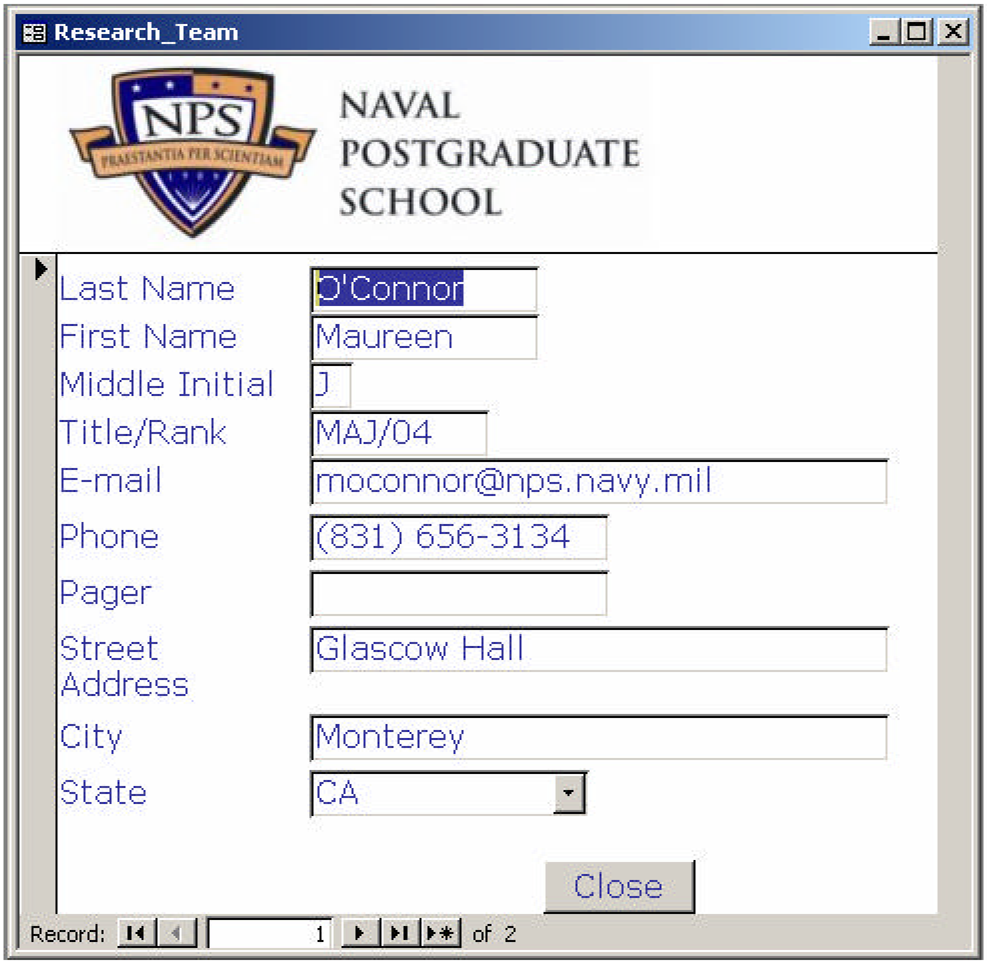
PDA Status Input Form



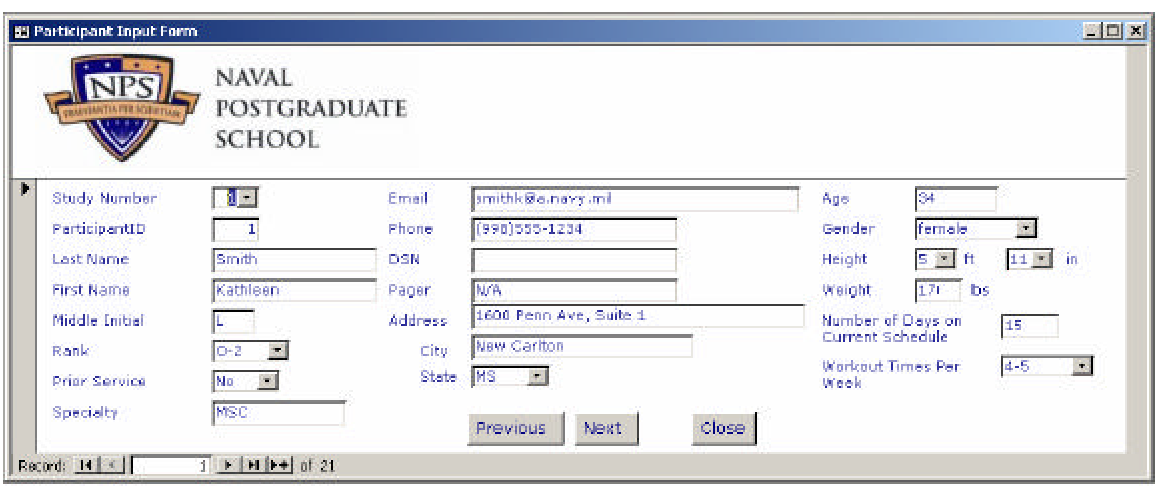
Study Input Form



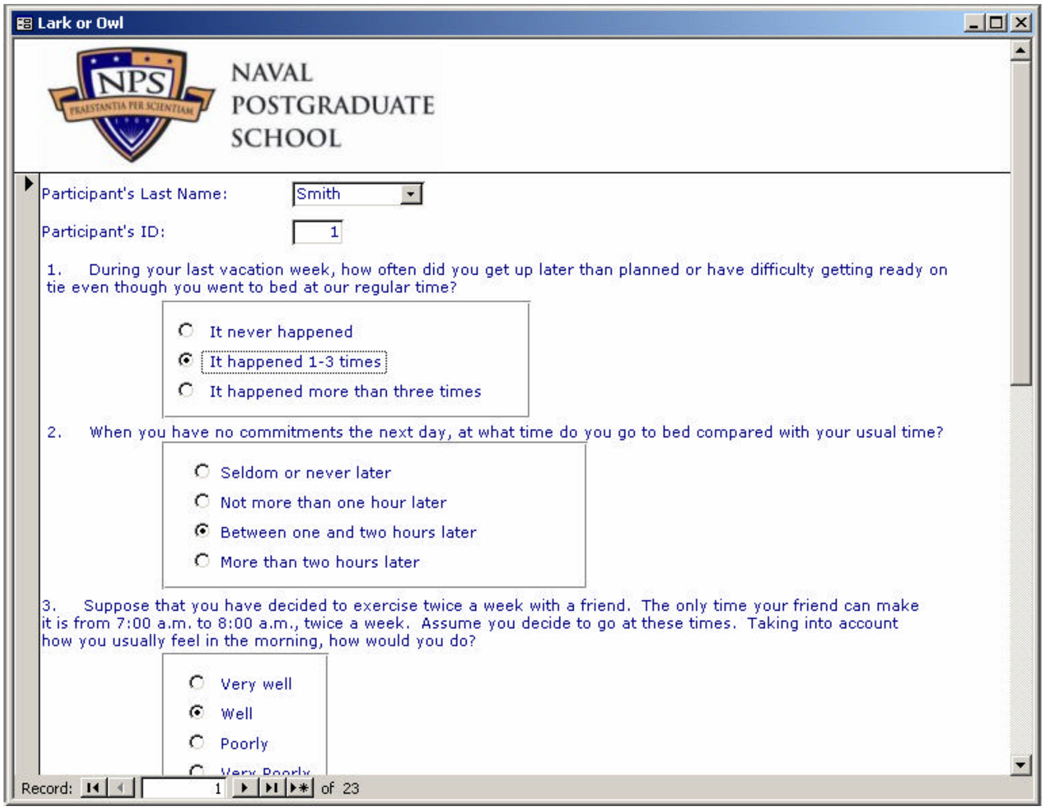
Research Team Input Form



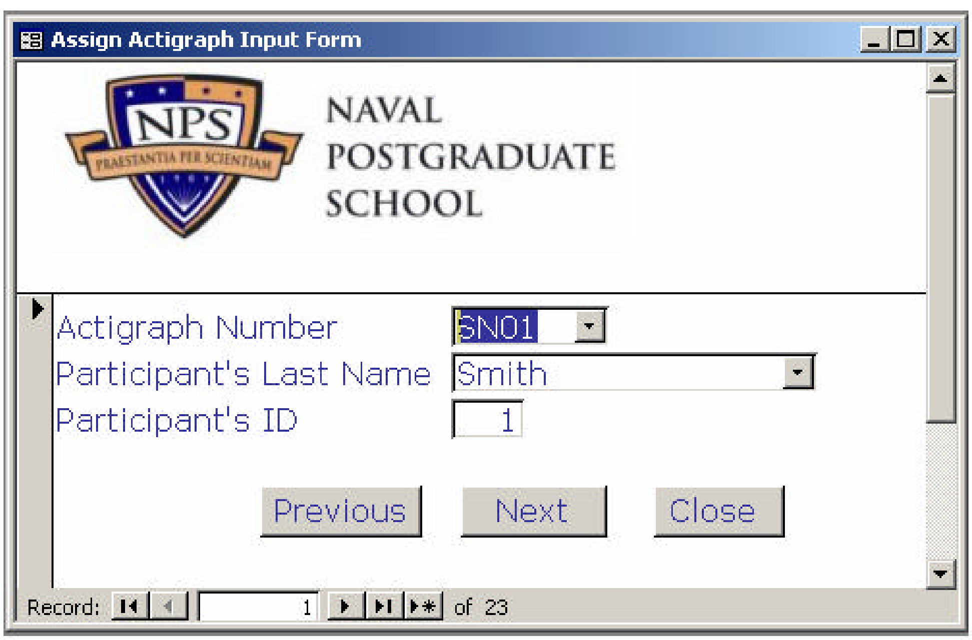
Participant/Demographic Input Form



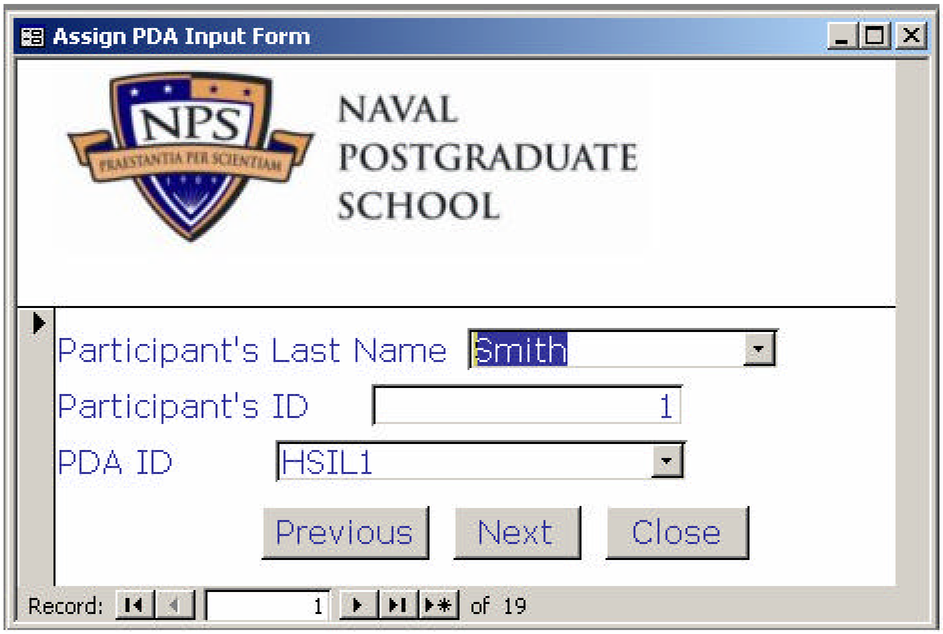
Lark or Owl Input Form



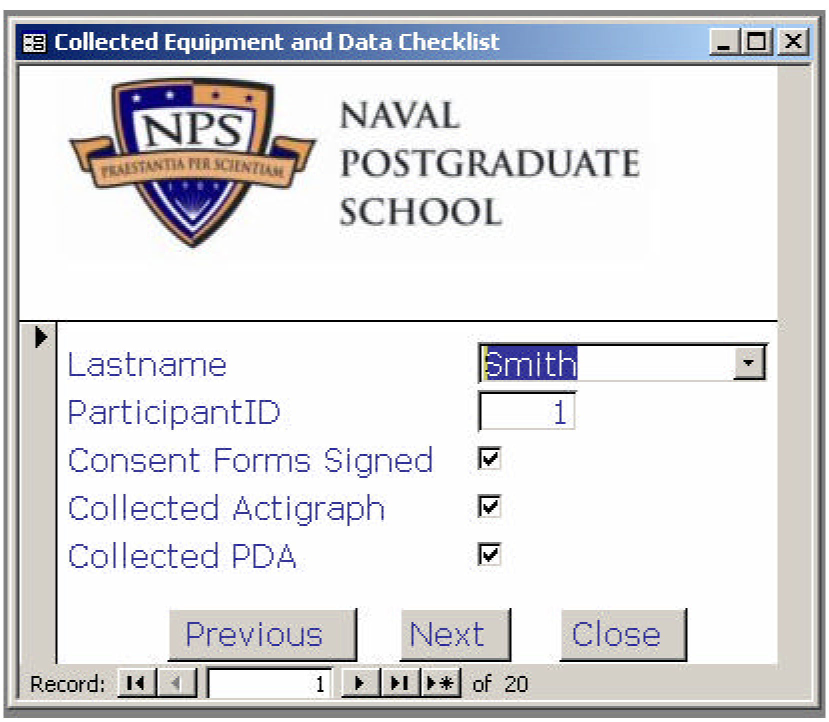
Assign Actigraph Input Form



Assign PDA Input Form



Collected Equipment and Data Checklist Form



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